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This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

E. S. CHESBROUGH.

A MEMOIR.

BY BENEZETTE WILLIAMS, MEMBER OF THE WESTERN SOCIETY OF ENGINEERS.

[Read October 5, 1886.]

Ellis Sylvester Chesbrough, past President and Member of this Society, died Aug, 18, 1886.

It is given to but few men to occupy so conspicuous and honorable a position in their profession as that filled by E. S. Chesbrough in the engineering profession. When the history of American engineering comes to be written, the period from 1830 to 1880 will be no more noteworthy as the formative era of the profession in this country, than as the era that produced a few remarkable men who lived to become connecting links between the earlier triumphs of American skill, and the greater works which in later years have placed the United States abreast of the most advanced nations of Europe in all that pertains to scientific engineering. In this small but honored group Mr. Chesebrough will occupy high rank. No Pantheon of engineering celebrities would be complete without him ; no historian of American construction can afford to omit his name.

Mr. Chesbrough was born in Baltimore County, Md., on July 6, 1813. His father, Isaac M. Chesbrough was a native of North Adams, Mass. His mother, Pharina Jones, was born in Baltimore County. His first paternal ancestor in America landed at Plymouth, Mass., in 1630. From his mother's side he inherited German and Welsh blood.

The Chesbroughs had been farmers until the father Isaac, soon after the birth of his son Sylvester, tried other business. In his business ventures he was unsuccessful, one of his failures putting a stop to his son's education when the latter was but nine years of age. The father's purpose to give his son a liberal education being thus thwarted, the son never afterward had much opportunity for schooling. From the age of nine to fifteen he attended school but about one year, most of his time being spent in work, a part of it in the service of mercantile houses in Baltimore.

In May, 1828, at the age of fifteen, young Chesbrough took the first

step which led, with scarcely an interruption, to the eminence he finally attained, by becoming chainman in a party engaged on a preliminary survey of the Baltimore & Ohio Railroad. Col. Stephen H. Long was at that time Chief Engineer of that road, he, as well as the engineer assistants in the employ of the company being officers of the United States Army, and graduates of West Point. Lieutenant Joshua Barny was in charge of the party in which Mr. Chesbrough found employment. While in this service as chainman, his natural ability early showed itself to the officers in charge, their attention being attracted by his taking notes of the work as it progressed. They were ever afterward glad to gratify his desire for knowledge, and to afford him every facility in their power to become acquainted with the principles and science of engineering; and as a mark of their confidence promoted him from time to time as the demands of the service would permit. Up to this time young Chesbrough had formed no fixed purposes as to his life work, but the opportunity thus offered was eagerly seized upon, and henceforth life held an aim in the new and inviting field opening before him.

In 1830 he left the service of the Baltimore & Ohio Railroad Co. to become assistant engineer in the service of the State of Pennsylvania on the survey for the projected Allegheny Portage Railroad, Col. Long being, as before, his chief. In 1831 he was assistant engineer, under Capt. Wm. Gibbs McNeil, on the Paterson & Hudson River Railroad, and served in a like position, under Capt. McNeil, on the location and construction of the Boston & Providence main line and on the Taunton & New Bedford branch. In 1836 he was resident engineer on a proposed railroad from Lowell, Mass., to Concord, N. H., under Lieutenant George W. Whistler.

On Dec. 23. 1837, he married Miss Elizabeth A. Freyer, of Baltimore. At this time he was engaged on the Taunton branch of the Boston & Providence R. R.

For two or three years ending in 1842 he was employed on the surveys and construction of the Louisville, Cincinnati & Charleston R. R., a part of the time as senior assistant to Major McNeil, and another part—after Major McNeil's resignation—as chief, or Acting Chief Engineer. During this service the road was built from Charleston to Columbia, South Carolina.

Among Mr. Chesbrough's subordinates during this Southern experience were Gen. John C. Fremont, J. P. Kirkwood, Alfred W. Craven and Geo. S. Green.

The financial panic of 1837 had been busy bringing almost every kind of business to a standstill. Public work was stopped and engineers thrown out of employment, and among them Mr. Chesbrough, who in the fall of 1842 went from South Carolina to Providence, R. I., where his father then lived. The following winter he spent in the workshops of the Stonington Railroad Company, learning the use of tools. In 1843 he purchased a farm in Niagara County, N. Y., adjoining that of his father, and tried farming for one year, but with such poor success that he was glad to return to engineering, which he did in 1844. From this time until 1846 he was successively engaged in the construction of the Stoughton branch of the Boston & Providence Railroad, the Ashburnham &

Brattleboro line, and the Pautucket branch of the Boston & Providence Railroad.

From 1828—when, as a boy 15 years of age, he entered the service of the Baltimore & Ohio Railroad as chainman—until May, 1846, when called to take charge of the western division of the Boston water-works, Mr. Chesbrough's engineering experience had been wholly in the line of railroad work. During these eighteen years we have seen a boy hardly half educated, rise rapidly from the position of chainman to the position of senior assistant and then to acting chief engineer. We have seen him win the confidence and esteem of the only trained engineers in the country, viz., those who had been educated by the United States, for the army. But we have not seen the process by which this was brought about, nor marked the influences which were working to form the character of the man as subsequently known. That he was quick to learn, diligent in his work, and possessed of personal qualities which rendered him a favorite of his superiors, goes without saying. That to well-grounded moral principles inherited from his parents was added a high sense of business and professional honor, the legacy from his superior officers, we can readily believe. No one who knew Mr. Chesbrough well could fail to become aware of the lasting gratitude he felt toward the West Point officers under whom he served for so many years of his early life. And when we remember that professional honor has always been maintained at a high mark by these officers, is it any wonder that in all his after life he showed the effects of these early influences?

Though the groundwork of his future success was laid during these eighteen years, it was not by the achievements of these years that he became renowned. The turning point in Mr. Chesbrough's career was the acceptance of the position offered him by the Boston Water Commissioners. Henceforth his energies and talents were to be devoted to hydraulic engineering; and into this field he was to bring the same aptness and discriminating judgment that was displayed in his railroad work.

As before mentioned, the position which he took upon the Boston water-works was that of engineer in charge of the western division. This embraced the Cochituate aqueduct and the Brookline reservoir, the aqueduct being 14.6 miles in length, leading from Cochituate Lake to the reservoir. The eastern division was at the same time placed in charge of William S. Whitwell. The plans for those works had previously been matured by John B. Jervis, and he was continued as consulting engineer. At this time Mr. Chesbrough was but thirty-three years of age, and as he was entirely unacquainted with hydraulic engineering, was loath to accept the position offered, but under pressure of his friends, and with the assurance that Mr. Jervis was to remain as consulting engineer, he accepted. He continued in this position until the completion of the work in 1849. In 1850 he was made sole commissioner of the works, and in 1851, on the formation of the Cochituate Water Board, was appointed the first city engineer of Boston. He continued in this position, in charge of the water and other city works, until October 1, 1855, when he resigned to accept the engineership of the Chicago sewerage commission, that had but just been formed to carry out a sewerage system for this city. While City Engineer of Boston he had, I believe, made some

study of European sewerage systems, so that he was able to approach the Chicago problem with some measure of preparation.

The commissioners of the first sewerage board were Wm. B. Ogden, Gen. J. D. Webster, and Sylvester Lind.

Mr. Chesbrough proceeded to prepare sewerage plans for Chicago, and in December of that year (1855) he presented a plan which was adopted by the Commissioners, and recommended by them to the City Council. After considerable opposition and much discussion, the action of the Commissioners was approved by the City Council, and the carrying out of the plan begun and prosecuted during 1856.

Though the sewerage system had been started upon what was deemed a satisfactory plan, it seems to have been the conclusion of the Board that it was best that their engineer should make personal investigations in Europe with relation to sewerage, and thereby more thoroughly qualify himself for carrying out the work upon which they had entered. On Dec. 12, 1856, the Board passed an order, "that E. S. Chesbrough, Chief Engineer of the Board, proceed to Great Britain and the continent of Europe for the purpose of examining the various methods of sewerage adopted there, and of taking such notes and drawings of the same as he may think necessary and of examining into their operation and into all matters connected with them, which may in his judgment aid in the further prosecution and perfection of the sewerage of the city of Chicago."

The duty thus devolving upon Mr. Chesbrough he proceeded to perform with intelligent painstaking. The result of his trip to Europe is embodied in a "Report of the Results of Examinations made in Relation to Sewerage in several European cities in the winter of 1856–57," dated March 25, 1858. In this report Mr. Chesbrough describes the sewerage systems of Liverpool. Manchester, Rugby, London, Amsterdam, Hamburg, Berlin, Paris, Worthington, Croydon, Leicester, Edinburgh and Glasgow. He then takes up the disposal of sewage, the manner of constructing and maintaining sewers and house drains, in detail; their cost and the effect of sewerage upon the health of towns and cities. He discusses to some extent the double system of sewers, and, lastly, draws conclusions with reference to the Chicago sewerage.

In closing the report he says: "In preparing the foregoing report, it would have been easy to extend it to a thousand pages, by drawing from the voluminous sources of information now in your possession. The difficulty has been to select and condense what seems to have some present or prospective bearing upon the sewerage of this city."

It is hard for us to appreciate the importance of this report and the effect it exerted not only upon the destiny of Chicago, but also upon other cities of the country. It may aid us in doing so, however, to remember that at the time it was written there was not a town or a city in the United States that had been sewered in any manner worthy of being called a "system." The few detached, badly planned, and badly built sewers that existed in some of the older cities had been constructed with little care as to the relation of one part to another, or to a connected whole; they had also been built with but small reference to grades, or proportions, or to the uses to which they were to be put.

This being perhaps the first really thorough and exhaustive study which the subject had received at the hands of an American engineer, and Chicago being the only city on this continent to proceed systematically with a sewage system, Chicago and Chicago's engineer soon became famous; and for twenty-five years thereafter E. S. Chesbrough was the recognized head of sanitary engineering in this country.

For twenty-four years, from 1855 to 1879, when Mr. Chesbrough resigned the city engineership of Chicago, the system designed by him was in his charge through his principal assistant, Mr. W. H. Clarke and Mr. Clarke's successor. In this time it had grown to 295 miles of main sewers, with 46,572 house connections, costing $5,048,809.78.

The water-works, like the sewerage system, had been built and maintained by an independent board until in 1861 a Board of Public Works was formed and charged with the care of all municipal works, including the water and sewerage works. The first Commissioners of the Board were Benjamin Carpenter, Frederick Letz and John G. Gindele. On its organization Mr. Chesbrough was made Chief Engineer, and hence engineer of the water as well as of the sewerage works.

The water-works were older than the sewerage system, having been designed by William J. McAlpin in 1851 and reported upon by him to the Water Commissioners of the city Sept. 26, 1851. The first water commissioners were John B. Turner, Horatio G. Loomis and Alson S. Sherman.

The works as planned by Mr. McAlpin were to provide for a population of 100,000 people, their capacity to be 3,000,000 imperial gallons in 24 hours. There were to be three iron reservoirs in the several divisions of the city. The water was to be taken 600 feet from shore by means of a crib and a 36-inch iron inlet pipe.

They seem to have been carried out by the Water Commissioners according to these plans, except that a shore basin inclosed with piles was substituted for the crib 600 feet from shore. Before the water-works were turned over to the Board of Public Works the shore basin had come to be a source of great annoyance. It was polluted by the river discharge, by breweries on the shore, and supplied fish to the city in a manner not calculated to meet with general approbation.

In his report of 1857 the superintendent of the water-works, Mr. B. F. Walker, speaks in high praise of the manner in which the lake basin was continuing to answer the purpose. But in its report for 1859 the Board speaks of the fish nuisance, and says that "The matter of extending the inlet pipe into the lake for a long distance, for the purpose of obtaining always nearly or quite clear water, has had the attention of the Board for a long time, and still has.

"The undertaking, however, involves an expense, and is attended with risks which cannot be estimated by those not familiar with the difficulty of placing and maintaining structures on our lake shore, exposed to lake storms."

The increasing necessity for better water seems to have been the mother of the Chicago lake tunnel, which came about in the manner as described by Mr. Chesbrough in the following language from the eighth annual report of the Board of Public Works:

"In 1860 one of the Water Commissioners, Mr. Edward Hamilton, proposed to sink a wrought-iron pipe 5 feet in diameter one mile out in the lake, to obtain a supply beyond the effect of the river. This project was referred to the Chief Engineer of the Board of Sewerage Commissioners to examine and report upon, with the request that he also take under consideration and report on the matter of erecting additional pumping works in such locality as shall secure a supply of pure water.

"The report made in compliance with the foregoing request did not recommend the immediate adoption of any plan, but discussed various projects. Among them that of a tunnel was suggested; but it was thought best to defer the whole subject until further examination and analysis could be made, in the hope that much of the complaint against the water supply might prove imaginary."

It should be said in this connection that in the last report of the Board of Water Commissioners, the one for 1860, five different plans were discussed, being the ones probably to which Mr. Chesbrough refers in the foregoing extract from the eighth annual report. These plans were: 1st. Extending a pipe a mile out into the lake; 2d. A brick tunnel of the same length; 3d. Removal of the pumping work to Winetka; 4th. Filter beds; 5th. A subsiding reservoir.

After the Board of Public Works was organized and Mr. Chesbrough made Chief Engineer the subject was taken up in earnest by observations on the lake and river, guided by chemical analysis. The results of these investigations satisfied Mr. Chesbrough that if water was taken from the lake opposite the water-works, that the inlet should be two miles from shore instead of but one, as previously suggested. Of all the plans proposed Mr. Chesbrough had at the time the second annual report was issued substantially decided upon the tunnel plan as the most feasible. In this report he discussed this project at length. During the year 1863 this plan was finally adopted by the Board and work upon the tunnel begun on the 17th of March, 1864. From this time the work on the tunnel steadily progressed, and on the 8th day of March, 1867, about three years after the work was begun, water was let into the tunnel for the first time.

The success of this undertaking in the face of the great opposition he encountered may be considered Mr. Chesbrough's greatest triumph. It was not merely an engineering triumph, but, as I believe in a much larger degree, a diplomatic triumph. No one can read Mr. Chesbrough's modest account of this undertaking in the eighth annual report of the Board of Public Works, describing the plan proposed and its origin, and narrating the manner in which one kind of opposition after another was overcome until the plan was approved by the Board, and then by the City Council, without conceiving a high admiration for the man who could conduct to a successful issue a scheme so fraught with imaginative difficulties. It does not detract one iota from the credit due Mr. Chesbrough, that, as the sequel proved, the difficulties were nearly all imaginary.

A humorous side of this history was the action of the public press, which, as Mr. Chesbrough says, had generally spoken favorably of the scheme until near the time that the contracts were let, when "they turned almost unanimously against it," and did not cease their warfare until the work was nearly completed.

The building of the second lake tunnel and the land extension of the same to the west side water-works followed as a matter of course. The ground having once been broken, subsequent work of the kind attracts little attention.

Mr. Chesbrough, as representative for the city, was one of the Commission which decided upon deepening the Illinois and Michigan Canal.

Among the other more notable works carried out by Mr. Chesbrough during his official connection with the city of Chicago, may be named the two street tunnels under the river, and the Fullerton avenue conduit, built for the purification of the North Branch.

While City Engineer of Chicago, and subsequent thereto, Mr. Chesbrough was called upon by numerous cities that wished plans for water or sewerage works, or that desired advice with reference to the same. Among the sewerage systems planned by him may be mentioned those of New Haven, Milwaukee and Indianapolis. He was consulted on the same subject by Providence, Memphis, Peoria, Dubuque, Des Moines, Burlington, Ia.; Chattanooga, Pullman, Denver, Buffalo and Winnipeg. He served on the Sewerage Commission for Boston, his associates being Mr. Moses Lane and Dr. Charles F. Folsom. This commission recommended the Boston improved sewerage project which has since been carried out. He planned water-works for Pittsburgh, Milwaukee, Jacksonville, and for Akron, Ohio, in some of which Mr. Lane was associated with him. He was consulted on the water question by Boston, Cambridge, Mass.; Toronto, Detroit, Albany, Memphis and other places.

He was engaged in a project for tunneling the Detroit River at Detroit and under the direct charge of his brother, Mr. I. C. Chesbrough, ran an exploration tunnel for some distance under the river. Partly from difficulties encountered in the operation, and partly from the opposition of certain railroad interests, the scheme was dropped.

He was afterwards consulted by the Canada Southern Railroad Co., with reference to a tunnel at Stony Island across the Detroit River.

In 1880 Mr. Chesbrough was appointed permanent consulting engineer by New York City for the new Croton water supply, and in connection with the Chief Engineer of the aqueduct, Mr. Isaac Newton, planned the Quaker Bridge dam and the new aqueduct, which is now being carried out mainly in conformity to the plans then agreed upon.

In 1882 the city of New York sent him to Europe to examine some high masonry dams in France and Spain, and to determine their bearing upon the proposed Quaker Bridge dam, which from its great height has been the cause of much unfavorable criticism.

During his European trip, while in Madrid, he was prostrated by the illness which finally terminated in his death. From this attack he rallied sufficiently to return to this country, landing in New York May 28, 1883. He was able, by a certain amount of injury to himself, to report the results of his examinations to the Department of Public Works in New York before coming home to Chicago. This act may be said to have terminated his professional career. From that time until his death he was an invalid, and even when he felt himself to be able for some light work, was not allowed by his physician to attempt it.

Mr. Chesbrough was one of the organizers of this Society, and served

as its President for many years. When in Chicago, and in health, he was constant in attendance. He was a man to whom the Society owes much, and by whose membership we are honored. He was also a valued member of the American Society of Civil Engineers, and for one term its President.

Mr. Chesbrough leaves a widow, two sons, and one grandson, all residents of Chicago.

There were elements in Mr. Chesbrough's character, as manifested in his daily work, which by unfriendly or superficial criticism could be made to appear contradictory.

He was extremely cautious in arriving at conclusions, and particularly so in making recommendations. This caution was frequently mistaken for indecision, when, as a matter of fact, it was but the careful weighing of the evidence before him. He was never a man who could form an opinion on one sided or partial evidence, so long as he believed there was more evidence in existence. He was ever disposed to give greater weight to experience and precedent than to conclusions evolved from the inner consciousness.

This, as we have seen, did not prevent his adopting bold projects, and carrying them to a successful conclusion. When he was inclined to recommend a bold plan of any kind, he would search high and low for some experience that could be construed in its favor, or against it.

Though in early life he did not have the opportunities for such scientific training as is afforded by the best modern engineering schools, his habits of mind and methods of arriving at conclusions were highly scientific. This lack of early training he always deplored, though to a mind constituted as his was, the deficiency was no great drawback to success. He was not content to apply purely theoretical deductions in practice, but must have an experimental basis for everything done by him. Not that the exact counterpart of a proposed structure must exist, but there must be some analogy between the thing proposed and something else that had become established on experimental grounds. This demand that everything done or recommended should conform to some well-established rule of practice, or be justified by a clear deduction from a verified hypothesis, saved him from many an error into which other persons with less exacting minds would have fallen. In this respect, his methods were essentially scientific.

The visionary or charlatan who selected Mr. Chesbrough for a victim of his folly, would not be long in discovering the mistake of such a selection. He could not be betrayed into the endorsement or the adoption of a wild scheme, however skillfully it might be put before him. If there was a fallacy in it he would sooner or later discover it. If there was no fallacy, but the reason upon which it was based could not be verified or made clear to him, he would hold it in abeyance pending such verification. If this habitual working of his mind led him to delay or to reject some really meritorious plan, it also saved him from many mistakes.

Still another quality of Mr. Chesbrough's mind was farsightedness, and nowhere is this quality better portrayed than in the public works of this city, to which the best years of his life were given. In view of what is going on relative to the water supply and drainage of the city, this may

seem to some a startling proposition. It is, however, these very works that render the truth of the proposition apparent. A careful reading of the report on sewerage made on his return from Europe, heretofore referred to, and subsequent reports relative to the same subject, shows that all the evils from which the city is now suffering were apprehended and means suggested for their removal in accordance with the best light then attainable. What wonder if the magnitude of the evils he then foresaw has exceeded his expectations? What wonder if the means proposed for their correction now seem inadequate?

Where else in the history of Chicago has a conception been formed as nearly commensurate with subsequent developments as that embodied in the water and sewerage works? Have the great corporations, railroad companies. gas companies, etc., shown an equal adequacy in dealing with the future? If there is one thing connected with the physical well-being of this city that should be a subject of profound gratitude, it is that the early development of the sewerage and water systems were dominated by so wise a forethought. With the accumulated experience of 30 years, since the beginning of the Chicago sewerage system, it is safe to say that the engineers who could undertake a similar problem, under like phenomenal conditions and not fall far behind Mr. Chesbrough in adequacy of comprehension, are few indeed. It is seldom the duty of an engineer to plan and execute an ideal conception; he is generally hampered by doubts and uncertainties as to the future on the one hand, and so restricted as to funds on the other that makeshifts often become his main reliance.

But with all these difficulties to contend with, where is the city that has had so few makeshifts imposed upon it as Chicago in the hands of Mr. Chesbrough? Who can deny that herein lies the evidence of his farsightedness.

He possessed a broad common sense which is as essential to a successful engineer as it is to success in the commoner affairs of life. He was diplomatic in meeting and overcoming opposition. In these, and in generalization, in forecasting probabilities, Mr. Chesbrough excelled.

His standard of professional honor was as high as the moral standard always maintained by him in all things. He invariably approached a subject with a mind unbiased by hope or expectation of personal aggrandizement. It was his fairness and impartiality, coupled with a cautious, discriminating judgment, that made his opinion valuable, and caused it to be sought for on many subjects.

If, professionally, Mr. Chesbrough's character was above an aspersion of dishonesty, privately, it was stainless. His walk was upright, and without a shadow. The highest Christian ideal, of doing justly, loving mercy, and walking humbly, was the rule of his life.

A noticeable trait of Mr. Chesbrough's character was the kindness and consideration he showed all other members of his profession, particularly the yong men who were seeking employment or information relative to engineering questions.

Socially he was genial and courteous in the extreme. In his official intercourse with all grades of men he was uniformly polite, whether it was the highest official he was addressing or the poorest and least

influential laborer. He would patiently listen to every complaint and right every wrong so far as it was in his power. None of his politeness and patience came of docility of temper, however, for he was naturally high spirited, and under great provocation could resent an insult with emphasis and indignation. No one could be more decided than he after doubts had been removed from his mind, nor take a firmer stand in opposition to what he believed to be an error, an injustice, or a bit of rascality.

"His life was gentle, and the elements so mixed in him that nature might stand up and say to all the world, this was a man."

CABLE RAILWAYS.

By Wm. H. Searles, Member of the Civil Engineers' Club of Cleveland.

[Read October 12, 1886.]

The use of cables for moving cars upon inclined planes is an old device, but it is only within a few years that cables have been applied to hauling passenger cars on our street railroads. On inclined planes there are usually two cars or trains at a time, the one ascending as the other descends; and the direction of the motion of the engine and cable is reversed at each trip. But on a cable road, the cable is endless and is constantly driven in the same direction on a circuit, while an indefinite number of cars may be attached to it on a double track road.

The cable road system was first introduced upon the Clay street hill of San Francisco, by Gen. Doubleday, Captain Ogden and Mr. A. S. Hallidie. The latter gentleman took out patents for various mechanical appliances used in connection with cable traction, and the present system is generally known by his name. It would seem as though the first intention was merely a modification of the old incline system, for the Clay street road, though only one mile in length, has a rise of 307 feet, and the steepest grade is at the rate of 16¼ feet per 100, or 858 feet per mile. The cable had a speed of six miles per hour, running 17½ hours a day. Notwithstanding the novelty of the plant and method of operation, the road was worked very successfully, and did great credit to the inventors and managers. The road began business in August, 1873, but it was three years later before another company ventured to adopt the system. This was the Sutter Street Railroad Company, which placed a cable on three miles of its line and has operated it ever since with marked advantage over the old system.

It was soon found that the cable system was as applicable to level roads as to steep inclines. There are now eight cable roads in San Francisco aggregating 43 miles of double track, all built on the Hallidie system.

In 1882 the same system was adopted in Chicago by the Chicago City Railway Company, which now has over 20 miles in very successful operation and five miles more under construction. Another company is preparing to operate several lines on the north side of the city.

In Kansas City one company has been operating three miles of line for

several years by cable, and has extended the line one and a half miles the present year. Another company is now building a line to be about three miles long.

In St. Louis, the St. Louis Cable & Western Railroad Co. began running a cable road three and a quarter miles long in April, 1886, and another company has a project for a cable road.

In Cincinnati the Mt. Adams and Eden Park Railroad Co. has been operating a mile and a half of cable road for a year or more, and will soon have three miles running.

Philadelphia has two lines of cable road, one of which is not running, owing to faulty construction ; the other is operated successfully.

New York has one cable road, extending north in Tenth avenue from 125th street, about three miles, and through 125th street to the Harlem River, about two miles. The latter portion is not yet completed, but the part in Tenth avenue has a heavy traffic. The line is the property of the Third Avenue Railroad Co.

There are in all about 87 miles of cable road in operation in the United States at the present time, more than one-half of which has been constructed within the last five years. The progress in the five years to come is likely to be much more rapid.

These roads are all built on one general plan, with, of course, some variations in detail. The track is level with the pavement, but is not laid in the ordinary manner. No cross-ties can be used, since they would interfere with the necessary communication between the cars and the cable. In constructing the road a trench is first excavated about three feet deep by two and a half feet wide along the centre line of each track. In the trench are placed cast-iron yokes weighing from 300 to 400 pounds each, at intervals of four or five feet. The yokes stand on the bottom of the trench, and by their shape give form to the conduit which is required for the cable, and by suitable arms support the track rails, which are bolted to them. They also carry a pair of slot-rails, so called, which are placed in the middle of the track and form the central cover to the conduit. The slot rails are of rolled iron or steel of a peculiar pattern. The tops are inclined toward each other, leaving between them, at the level of the pavement, a slot or longitudinal opening three-quarters of an inch wide, which extends the entire length of the track. The slot-rails stand 7 or 8 inches high, and their bases are 6 or 7 inches apart. They weigh 50 to 60 pounds per yard each. In some cases the yokes have been made of railroad iron bent to the proper shape and braced with angle iron. These yokes were of less weight, but being more elastic they yielded to the lateral pressure of the trench and pavement, and thus allowed the slot to close, giving a great deal of trouble in the operation of the road. Where the strength of the yokes is not sufficient to keep the slot rails apart, the latter are anchored back to the track rails with half-inch rods. The conduit is built of concrete, requiring 35 cubic yards per 100 feet of single track. The conduit is either oval or rectangular, according to the shape of the yoke adopted. The St. Louis conduit is lined with sheet iron ; that in Cincinnati is lined on the sides with plank previously treated by a preserving process, and on the bottom with a coating of pure cement. Plates of iron are

employed to cover the spaces between the walls of the conduit and the bases of the slot rails. Carrying pulleys are placed at regular intervals within the conduit to support the cable. They have a face of 4 or 5 inches slightly concave, with a central groove about $\frac{3}{8}$ inch deep for the cable. Their diameter is 12 or 14 inches. (Sheaves of only 9-inch diameter wore out very rapidly.) They are fixed on shafts of $\frac{7}{8}$ to $1\frac{1}{8}$ inch diameter, and from 9 to 13 inches long. The methods of mounting are various, but the later preference is for steel shafts in boxes of babbitt-metal. The ruder forms of mounting wear out too readily, and consume too much power. The sheaves clear the bottom of the conduit by several inches to allow the passage of water and mud which may get in through the slot. On curves a series of horizontal sheaves are used. These sheaves vary in diameter all the way from $14\frac{1}{2}$ to 42 inches. Sizes from 19 to 29 inches seem most desirable, and on curves of short radii they are placed as close together as possible. The conduit is enlarged to accommodate them, and yokes of special forms are provided ; cast-iron covers over them are substituted for the ordinary pavement. The shafts are usually 2 inches in diameter, and are provided with both upper and under bearings in babbitt boxes.

The cables are $1\frac{1}{4}$ inches diameter of steel wire, 19 wires to the strand. The cable is not placed directly under the slot, but a little to one side of it. The length is generally limited to five miles. The St. Louis cable is over 34,000 feet long. The breaking strain, when new, is about 39 tons. A cable in constant use lasts 12 or 14 months, in which time it will run from 85,000 to 100,000 miles. When condemned, it will have lost perhaps 10 per cent. of its weight and 40 per cent. of its strength. Very much depends, however, on the excellence of the pulleys and other machinery, and freedom from mishaps. The splice of a cable is 19 feet long, one end lapping by the other this distance. It requires the services of several men specially trained for the work, and occupies them three or four hours. When completed, the splice can hardly be detected in a running cable. The cable speed varies from seven miles an hour in Kansas City and seven and a half miles an hour in St. Louis to ten miles an hour in Chicago. The new line in Chicago, in the suburban district, is to have a speed of twelve miles an hour. Motion is imparted to the cable by heavy machinery specially designed for the purpose. The engine-house may be located at any convenient point along the line. The highest point of the grade would doubtless give the easiest working, but this consideration seems not to have been regarded on any of the recent roads. The cable, on entering the engine-house, passes around two drums, giving a half wrap to each successively until two or three wraps have been made. It then passes to the rear and over a tension wheel, whence it returns to the street to repeat the circuit of the road. The drums are of cast iron, 12 feet in diameter, and have four or five grooves on the face to receive the cable. The grooves are parallel, and each returns into itself. The shaft of one drum is horizontal, but the other is slightly inclined, so that the first groove on one drum may be directly opposite the second groove on the other. Both drums revolve in the same direction, a large gear wheel on each shaft being connected with the other by an intervening pinion. One of these gears is driven by another pinion on a

main shaft, which is in turn geared to the engine shaft. The effect of this gearing is to give the engine shaft about three times as many revolutions as the drum shaft makes per minute. When new, the drums are of equal diameter, and both impart motion to the cable ; but if one drum should wear more than the other in the grooves, so much friction and jar would be produced that the intervening pinion must be removed, allowing one drum to act merely as an idler while the other does all the work. This is now the case in St. Louis and Cincinnati. In New York, on the contrary, the machinery is in full gear, yet operates almost noiselessly. In the main engine-house of the Market street line, San Francisco, the drums revolve in opposite directions, the cable taking three-quarters of a circumference on each, in the form of a figure 8. The gears mesh directly together with V-shaped teeth, and are driven directly from a pinion on the engine shaft.

On every line duplicate machinery is provided as a reserve in case of accident. In New York, even a duplicate cable is placed in the conduit on separate sheaves. The same arrangement was originally made in Kansas City, but has since been abandoned as too complicated, and increasing the difficulties when an accident occurs.

The tension wheel is designed to take up the slack of the cable, which varies considerably in amount, and to give to the cable as nearly uniform a tension as possible. The wheel, which is 12 feet in diameter, is mounted on a simple carriage, which is free to move on a track laid in the line of the drums. A weight attached to a chain passing over a pulley draws the carriage away from the drums until resisted by the loop of the cable on the tension wheel. When the strain on the outgoing portion of the cable is greater than one-half the weight, the carriage yields until equilibrium is again established. The carriage is thus constantly in motion in one direction or the other. A pair of heavy spiral springs attached to slack chains prevent the carriage from running too far forward, as it frequently would do under a suddenly applied strain.

The engines are of the horizontal non-condensing type, with automatic cut-off of approved pattern. The usual size of cylinder is 24 inches by 48 inches. The New York engines are 28 inches by 48 inches, and the new engines in Chicago are 30 inches by 60 inches. The speed is generally from 60 to 65 revolutions per minute. The Kansas City engine makes only 45 revolutions per minute, while that in Cincinnati makes as high as 78 revolutions. Each engine has a heavy fly-wheel from 16 to 18 feet in diameter, and weighing from 3,400 to 40,000 pounds. The engines are rated at from 250 to 300 horse-power each. The boilers and furnaces are of various patterns according to the preference of the party ordering them.

There are, of course, various other details of more or less importance connected with the cable system, which time forbids to be mentioned here. This paper, however, would not be complete without some description of the grip, an ingenious device for laying hold of the cable at will, so as to make it haul the car, and of loosening the hold again when the car is to stop. The grip consists of an iron frame attached to the centre of the car, from which an iron plate extends downward through the slot in the track into the conduit. On one side of this plate, near its lower

edge, is attached a bar of composition metal called a die, about two feet long, parallel to the cable, over which the cable passes. A little roller at each end of the die saves the cable from abrasion. Another die attached to another plate is made to come down upon the cable, gradually increasing the pressure until the car begins to move, and finally seizing the cable so firmly that the car is carried along with the same velocity as the cable. The upper die is operated by a lever in the car. To stop the car the lever is reversed, allowing the cable to slip through the dies, and ordinary brakes are applied to the wheels. The grip does not extend far enough down to interfere with the carrying pulleys, nor does it touch the curve pulleys, which are placed a little to one side of the centre line. When necessary, the cable can be thrown out of the grip entirely by a lever motion in the car. A number of variations in the design of grips have been patented by different parties. They all serve the same general purpose more or less efficiently. Indeed the grip has been to the cable system, like the point-threaded needle to the sewing machine, simply indispensable.

On the whole the cable system has commended itself wherever it has been adopted in our cities. It gives to the public much cleaner and quieter streets than the horse-car system can. It affords a more rapid transit, and a more uniform speed in all weathers, at all hours and over all grades. It avoids the distressing spectacle of overstrained horses struggling to start a crowded car, and slipping and sometimes falling in the attempt. It avoids all delay from balky animals. It promptly increases the value of outlying real estate in the vicinity of the line. To the railroad company it gives the advantage of a largely increased business, resulting from greater promptness and efficiency in operating the line—qualities which are quickly appreciated by the public. But it also effects a decided reduction in the current expenses of the road. In the case of the Sutter street road of San Francisco, three miles of which were changed from horse to cable traction, the sworn testimony of the officers shows that the actual saving in expenses was 30 per cent., notwithstanding the fact that the business of the road was increased $962,375 in the first year of the cable. Other companies have experienced even a greater saving than this, amounting to as much as 36 per cent.

The main objection to the cable system is its large first cost. A double tracked cable road laid in the best manner and supplied with girder rails, will cost, exclusive of pavement, at the rate of $65,000 a mile ; or, adding $25,000 a mile for first-class pavement, will bring the cost up to $90,000 a mile. The necessary buildings and plant may be estimated at from $60,000 to $100,000 according to circumstances. The supply of cars will be an additional item. When an existing horse car line is to be altered to a cable line the expense per mile is not much less, since the old track has to be entirely removed and the new road constructed instead. Some of the old material may be available. Among the minor objectionable features is the grip. It takes up considerable space in the car otherwise available for passengers ; it confines the car to the track, and prevents the car from going where there is no conduit. The plates soon become worn by contact with the slot rails, and the dies require renewal once a month. The first cost of a grip is about fifty dollars, and the bill for repairs is

continuous. It is true that the Lane grip used in Cincinnati may be detached from the car, and occupies no passenger space, being under the car, and operated from the front platform, but it is subject to wear quite as much as any other.

The great desideratum, therefore, at the present time is a cable system of much less first cost, that can be applied to existing horse-car lines without destroying the track, that will permit the use of cross ties, and that will dispense with the use of the grip. A new line, with which the writer has been for a short time connected, is now under construction in one of our largest cities. It is constructed on an entirely new plan, and is designed to fulfill every one of the above requirements, yet to be operated as cheaply and as certainly as any other cable line. The road will be completed in a few months, and should it fulfill the expectations entertained regarding it, we may look for a speedy revolution in the operation of our horse-car lines.

ABSTRACT OF DISCUSSION OCTOBER 12, 1886.

Mr. H. F. Dunham : Does that saving of 33 or 36 per cent. include interest on the cost of the road ?

Mr. W. H. Searles : No, it is the regular operation of the road, a comparison of power and wear and tear with the horse power. Our horse railroads are very expensive.

Mr. Rawson : Does not the Chicago system require a relay of horses ?

Mr. Searles : Chicago has still some lines operated by horses, but no horses are required on the cable lines.

Mr. Rawson : I have been informed that there was a relay of horses required in case of break down of cables.

Mr. Searles : There are such horses for some lines, and they could be used if necessary, but as yet there has been no serious delay, not more than a few minutes at a time.

Mr. Clark: I understand that the axes of the drums are at an angle one with the other. To bring the bottom of the first slot in line with the second slot, what gearing is used ?

Mr. Searles : The first drum has square gear. The last drum has regular square teeth. Its shaft is inclined a little out of the horizontal, and the teeth have a slight inclination corresponding to that of the shaft. The cable has to be lifted first for the grip to seize it. The grip cannot be lowered or raised. There is a form of grip which can be lowered or raised, but it has not been adopted. It would be desirable if the grip could be let go at certain places. At St. Louis they have sharp curves, but they dare not loosen the grip, as they could not recover the cable again.

Mr. Baker : Is the cable supported by the grip ?

Mr. Searles : Yes, so that it does not rest at all on the pulleys near the grip. The grip clears the pulley by several inches. It also clears the curve pulleys by being a little above them, and also by reason of their being slightly off the centre line.

Mr. Rawson : Could you give us some idea of the Johnson cable ?

Mr. Searles : That is almost too much for this evening. It is entirely

different from what I have described. I may say that although the road now building in Brooklyn is the first road of this new cable system laid in a street, such a road has been in operation in this city for a year. However, it is only one-eighth of a mile long, and is inclosed with a high board fence. The experience gained warrants us in hoping that the new road will be prepared to do business on a large scale as soon as completed.

A Member: What amount of horse-power will it take to move the cable?

Mr. Searles: 11 horse-power on tangents and 12 and 14 horse-power on roads with curves, at ordinary speeds.

Mr. H. F. Dunham: What relation does the total horse-power of the machinery bear to the number of horses required to do work where 500 horses would be required to move the cars?

Mr. Searles: It comes very near to two horses per car, including friction of the cable and friction of the driving machinery. In Chicago they run trains of cars. The grip-car generally hauls two others. All three are loaded with passengers. Of course, the strain on the grip is more than on two horses.

Mr. Dunham: Horses are employed only eight hours in the day, and the cable runs continuously.

Mr. Searles: I have been informed that the horses on the East Cleveland Railroad are only worked two and a half hours a day, and yet they soon break down.

Mr. Warner: The size of the cable is an inch and a quarter. Is this reduced by use?

Mr. Searles: It wears out in 12 or 14 months. It is reduced in weight about ten per cent. when condemned. This shrinkage in weight is due to what is worn off of the diameter. Sometimes the stretch of the cable is so great that they have to take an extra wrap on the drums. These drums are overhung at the very end of the shaft, to admit of an extra wrap without splicing the cable.

Mr. Pierce: Has Mr. Johnson made a cable out of the quarter-inch thick wire, and is it pliable enough to go over the drums of 10 or 12 feet? It appears to me that a cable made of that wire would be very stiff.

Mr. Searles: This cable is made of number 3 steel wire, 6 wires to the cable. There has been so far a hemp centre, but in the future we wish to use a centre made of fine steel wires. The cable goes round a 12 foot drum without difficulty, even less, down to 9 feet diameter. After passing round it comes out as straight as ever. It is not a single cable, it is a pair of cables. This double cable measures two and a half inches across by three-quarters diameter.

Mr. Pierce: You bind these two cables together?

Mr. Searles: That is the design. The cross bars or stops occur at regular intervals. They are continued in the space between the cables, and are no thicker than the cable, so that there is no interference with the cables wrapping on a drum or passing any pulleys.

Mr. Baker: What is the idea in using such a large wire?

Mr. Searles: The idea is to get rid of the grip. This double cable will go round a sharp curve flat. It is always in the centre of the track. It

is always within two inches of the surface of the pavement. It is always accessible to the car. But you can let go of it if you please at any time.

Mr. Dunham: How does the going round in such a horizontal curve affect the stretch of the cable?

Mr. Searles: The outside cable is stretched the most, of course, but quite well within the limits of elasticity.

Mr. Latimer: I have just returned from Cincinnati. While I was there I visited the station of the Cable Company. I observed that they came to Cleveland for their boilers, to Akron for their cable and gearing wheels, and I am only surprised that they do not come here for the Cummer engine. I noticed in one street that we went round the curves more easily than in any street railroad on which I had been. The engineer told me that they were using Mr. Searles' spiral curves. You are aware that Mr. Searles is the author of a work on that subject. While I was making some observations the whole system stopped. Every car on that road was stopped for half an hour. The engineer told me that the driver had failed to let go his grip and the cable was thrown off the wheels. They have been running engines of 250 horse-power, but they have just set up a new one of 500 horse-power. They have overcome entirely the closing of the slots by using a cast-iron frame. They have a three quarters of an inch slot. This road costs $35,000 per mile against $110,000 in Chicago. Their cables last about eleven months.

Mr. Searles: One lasted 14 months in San Francisco. That was an extreme case.

Mr. Latimer: Since the introduction of the cable system the value of real estate has been much advanced in Cincinnati. We must get these cable roads in Cleveland.

WATER METERS.

By. J. A. Tilden, Member of the Boston Society of Civil Engineers.
[Read November 17, 1886.]

It is the intention of this paper to sketch the development of the water meter as a mechanical device. All questions as to its value as a means of checking waste and as a method of equitably adjusting rates are not considered here, but may be said to be answered by the constantly increasing demand for an efficient and cheap meter.

The history of its development as a piece of mechanism may be traced in the Patent Office; and it is from the patent records of the United States, England, France and Germany, and from a few scattered publications that the data of this article are taken. The observations submitted are the result of practical experience in a long series of experiments, and are offered simply as opinions.

It is remarkable that upon a subject of such importance so little has been written. The same unprejudiced thought and study as has been given the steam and other engines is entirely wanting. It appears to have been studied only by inventors and experimenters who have carefully guarded their work and reserved their conclusions for themselves. Every other form of engine or motor (for a meter is but a special

adaptation) has been fully elaborated, and there are many authorities upon every subject theoretical or practical connected therewith, while upon the water or fluid meter information as to its mechanical or operative details is almost entirely wanting. It was on this account that the Patent Records were searched as a record of experimental work. As to their value as a source of information or authority, it will be seen that each specification must be read with caution, as many conceptions therein described do not even reach the experimental stage, while by far the larger proportion are abandoned by the time the patent is printed. A search as to novelty should comprise, and in the United States Patent Office does comprise, not only the class of meters but that of engines, motors and pumps, and of specific parts. A task of this kind is truly formidable, for to be complete it should comprise a search of record in all patent granting countries.

The United States patents—class of meters—number at this reading five hundred and fifty-two ; those of England and Colonies nearly as many more, and the number is well approached by the sum of those of France, Germany, Belgium and others. Here will be found the names of well-known engineers who have considered the water meter worthy of their expert attention, and who have produced some very excellent machines ; while on the other hand, it has decidedly suffered at the hands of the entirely inexpert and ignorant, who have succeeded only in shrouding it in a kind of mystery and in producing the common impression that a successful meter is about as unattainable as perpetual motion. While an enormous amount of money has been expended in experiments, the total number of patents probably representing but a part, only a small portion has been utilized in well executed design, as shown by the very few efficient devices in the market. If this statement is true, there must have been some special difficulty peculiar to the problem. It can be shown that if one element, that of cost, were eliminated, mechanical defects could be easily overcome. Efficient and cheap it must be in order to meet a demand which does not exist for a high-priced machine. It is the cost at which it must be produced which makes its duty and requirements in excess of almost any other automatic machine.

There are a number of excellent meters in use whose operation may be said to be practically all that is desired, their limited application being not on account of any defect, but because of their high price, which arises from their size, weight and cost of manufacture. It may be noted here, that in a comparison of economy of meters, durability and permanency are as great a factor as price.

Ideas of what constitute efficiency vary with almost every water department. Special prominence is generally given to one particular feature to the oversight of others of equal or greater importance. However, they average up about as follows : To be efficient, a meter must be accurate within a permissible error, under extremes of pressure and rates of flow of perhaps two per cent. in favor of either department or consumer, and must maintain this standard with a reasonable, or rather an unreasonable, degree of permanency. It must not materially or noticeably retard the flow or diminish the pressure, and should be able to pass, without stopping, clogging or breakage, substances often carried along

with the water, such as sand, sediment, pipe scale, etc. It must be able to withstand without damage water hammer caused by sudden closings, and in itself produce none, or make any noise from its working parts. Altogether, it must be compact, of non-corrosive material, inexpensive in repairs, and capable of standing abuse rather than use. It will be observed that a number of these requirements are not inherent in a measuring apparatus, but have been introduced by the defects of meters themselves.

Of the United States patents on meters two hundred and thirty-nine are of the piston type, one hundred and eighty-three are rotary, fifty are diaphragm, and eighty are oscillating. There are in addition a number of miscellaneous which admit of no large classification, such as those of the purely inferential and proportional type.

The reciprocating piston meter in its severally perfected forms is a practical measuring device, its efficiency being limited only on account of its large cost arising from the expensive non-corrosive materials used in a necessarily bulky construction. The mechanical problems of a piston meter have been fairly met. It is required that a piston be forced by water controlled by a suitable valve device to traverse a cylinder and return to its starting point. The amount of water displaced or measured per stroke is equal to the area of the piston into the distance which it travels. Connected with a properly constructed counter or register the mechanism is complete. According to the records it would appear that this class of meter was as near perfection thirty years ago as it is to-day. Of more than two hundred United States patents in this line but two or three have met with popular favor and are able to meet the market at anything approaching the required price. The others, which in many instances show great ingenuity, have either misconceived the object sought for or utterly failed mechanically. Many large and costly meters have been designed under the impression that there were no good piston devices in use. These, of course, although they may be efficient, are unavailable on account of their cost. The mechanical failures above mentioned are in most instances absurdities in the outset.

The best forms of the steam pump and other piston engines have their adaptation in more or less practical water meters. A special arrangement of the parts is made whereby the valve mechanism is entirely inclosed, and in such manner that there are no moving parts or connections outside the case. The duplex pump is represented in a double plunger meter in which a pair of double-acting plungers operate in conjunction with a pair of slide valves. The single pump is represented in various forms of single piston meters in which the valve gearing is operated by a supplemental piston and valve, or by weights, springs, etc. These and other modifications of reciprocating engines, while quite effective are large and heavy, and consequently costly.

In order to come within the narrow limits of price, many attempts toward a reduction of size and weight have followed, and as a result some of the special requirements of a meter have been sacrificed. As an instance, in the attempt to make a single piston do the work of two an infinite variety of valve mechanisms have been devised with a view of obtaining the same easy movement found in the best double piston

meters. The uniform result has been that either the single piston meter must be made large enough to equal in capacity the double piston or one of the following defects would ensue:

First: A mechanical noise caused by the striking of the moving parts, such as would come of the use of levers, weights or springs in obtaining a reverse movement of the piston, or in the use of a supplemental valve, by the main or auxiliary piston striking its bunters.

Second: Water hammer caused by the checking of the flow at the instant of reversal of the main valve; or, third, if this is avoided by the use of poppet or open, slide or piston valves, an annoying inaccuracy of registration ensues from the varying loss of water under different conditions at the time the valve is changing. The double piston in one of its best forms operates upon precisely the same principle as the steam end of a duplex pump, the piston, or plunger as it is in the meter, moving a slide valve which controls the water for the other plunger, which in turn operates a valve for the first. All piston, valve and connecting rods are dispensed with, as the valves are inside of the case and moved by direct contact with the plungers.

Attempts to lessen the high cost of this design have led to a great many experiments, such as the dispensing with the valves by the use of one piston as the valve of the other, by placing one inside of the other, by placing them at right angles, by the use of one rotary or slide valve operated with or without cranks and in every other conceivable relation. All this with poor success in the way of a meter at a less cost, serving only to complicate parts or introduce some peculiar defect of its own.

Vibrating or oscillating pistons have been tried in many forms with little satisfaction, as the increased cost of construction overbalances the reduction in weight.

Flexible diaphragms have been substituted for the piston, and combined with every valve gearing found in the piston and oscillating types, but still the diminution of size and weight is not found.

The opinion is submitted that almost any positive displacement device constructed on good mechanical principles, and, of course, specially adapted for the work, would be a mechanical success as a measuring apparatus, and would be a commercial success were it not for the rigorous lines drawn by the very limited price at which it must be produced and sold. In the attempt to meet this cost feature by a diminution in size, overwork of one or more parts or a general overcrowding is the inevitable result, causing either rapid wear or some of the immediate annoying defects, such as mechanical noise, water hammer, stopping, small capacity, inaccurate or uneven registration, etc.

There is a large class of inferential meters which come under the head of Rotaries; all measuring wheels, turbine screw and reaction come under this class, as they infer that for a given number of revolutions a certain amount of water will pass. It can be seen and experience has proved that only an unsatisfactory approximation is the result. Many, however, are yet in use in England, Germany and other foreign countries, as the piston meters made and in use there are very expensive. The purely inferential meters are those which infer that a certain amount of water will pass through an orifice, the size of which is controlled by the flow. Regis-

tration is obtained and figured from a recording gauge, which is operated by a piston or other valve at the orifice. A degree of success has been obtained in this way on large pipes.

Proportional meters were among the earliest conceptions for the registering of water in large quantities. In these a relatively small portion is deflected from the main pipe and measured by positive displacement, the principle being that the fluid will divide proportionally under relatively equal resistances. It has been found that, on account of the varying retardation of the metered part under the different conditions of pressure and flow, a regulating valve of great delicacy is required to deflect the proper quantity from the open pipe to the meter, according to the reductions of pressure at the point of discharge. The serious defects are, first, the multiplication of error, which is in the same proportion as the unmetered part to the metered; and, second, any clogging or imperfect action of the regulator may put the entire amount through the meter, or, under other conditions, none through it, and the whole through the pipe without registering. This plan, as yet, has met with little favor, and may be said to have scarcely gone beyond the experimental stage. Its entirely inferential character and great delicacy renders it little more than a guessing machine.

A number of devices such as tilting tanks, floats and weighing wheels are simple and effective where they can be used for delivering water without pressure into a tank, but, of course, are entirely unavailable for the market, as the introduction of a meter on a pipe must not reduce or affect the pressure.

A positive displacement rotary, in distinction from the turbine or screw wheel type, has constantly been sought for as the solution of an efficient low-priced meter. The same observation applies here as in the reciprocating piston. Almost any reasonable, well constructed rotary piston will measure water if not overcrowded, but with few exceptions they would have to be made so large as to be unavailable, or, if reduced in size, are sure to introduce the same defects as noted in the reciprocating meter. Friction and consequent wear and inaccuracy has been an almost unsurmountable obstacle in the path of a small piston rotary. Until within a few years the only device of this kind meeting with any degree of success has been the double piston rotary, and this at the expense of delicate and costly workmanship. The style referred to is on the same general principle as the double-gear piston found in several patterns of steam engine pumps and blowers.

A step of great importance has been taken in the combination of a casing and one piston in such a manner that the piston may move within its case dependent upon no journals or bearings. The effect of this is so far to reduce friction and increase operative areas as to bring the meter within a very small compass. Were it not for one fault, and one which is singularly developed as a special defect, the liability to stop by the wedging of a minute particle of sediment between one of the many contact surfaces offered by their peculiar design, this improvement would have proved the meter ultimatum. The introduction of this class of meters in Western and other cities, where river water is used, and in many other places where the water contains a large amount of sediment, has necessarily been limited.

There has been a special effort toward the designing of a meter which shall remove the defects of uncertainty and unreliability so long characteristic of all rotaries without sacrificing any of the advantages obtained by the use of a non-rotating piston. This end is accomplished in a class of meters in which the piston is perfectly free and loose in its case. It is confined in its path only by the pressure of the water in distinction to all others which divide the case in such a manner that the piston is held in a rigid mechanical path. This feature enables the piston to ride over substances which would lock any rotary whose piston is mechanically confined or rut and wear out any reciprocating meter.

There is developed in all modification of this class a self compensating feature by which a seeming paradox is actually accomplished, the fit of the parts is improved by use. A small excess of pressure on one side of the piston serves to maintain its contact on the other, giving by continued service a fit superior to the best mechanical grinding. Acting as its own valve, it is perfectly balanced by the duplicate porting of the plates between which it runs. Too much importance cannot be attached to balancing the moving parts especially in a high-speed meter, using the expression in the same way it would be applied to an engine.

The lifetime of a meter is determined by the wear of its parts, which in turn depends upon the friction. Tight fitting is to be discouraged, as it is productive of friction and inaccuracy. It is evident that in order to reduce a meter to the size required by a marketable price, the working parts must move with great rapidity. That is to say, if it is desired that a very small part do the work of a large one, it must of course move very fast. This means the use of a revolving piston in preference to a reciprocating. It is obviously impossible for a reciprocating piston to attain the speed in a non-elastic fluid that a continuous motion or revolving piston is able to reach. In view of this, it is thought that this rule will apply. All moving parts in a high-speed meter must be either balanced in action or compensating for wear. In the syle of meter last referred to this rule is applied to a marked degree. The principle involved is susceptible of many modifications. An illustration is found in a meter in which the piston—which is made of hard rubber on account of its lightness and great durability—moves in a circular path, but does not in any sense rotate on an axis real or imaginary. It has six radial projections, which in turn enter six measuring spaces or recesses in the casing, which is also of hard rubber, and by dividing each into receiving and discharging spaces operates upon precisely the same principle as piston and cylinder displacement. Three of the six projections are at work in their respective recesses at a time, and the same relative side of each being by the arrangement of the ports open to the inlet, and the other side to the outlet, a continuous motion and flow is effected. At the same instant that one projection leaves its space another one on the opposite side commences to work. The piston carries a pin which drives a registering train, and as a certain uniform amount is discharged per revolution, proper gearing reduces it to cubic feet, the unit of measurement. It is believed that the improvement of a "free piston" so far reduces internal friction as to materially increase the efficiency of the rotary meter, the consequent gain in durability more nearly approaches the requirements of cost.

STREET PAVEMENTS.

A DISCUSSION BY MEMBERS OF THE WESTERN SOCIETY OF ENGINEERS.

In answer to the query, referred to the Committee on Streets, at the meeting June 1, 1866, "What is the best pavement, or improved roadway, for a city residence street having a limited amount of travel?" the following discussion was had:

C. P. Matlack, San Antonio, Texas: During the last year I have put down about four miles of gravel roadway on a Telford foundation. These are the specifications for the roadway:

"The earth roadbed on which the pavement is to rest is to be excavated to sub-grade twelve (12) inches below and parallel with the legal grade and finished surface of the street; and, when graded and shaped to its proper form and cross section, it is to be thoroughly and repeatedly rolled with the steam roller, and all depressions which then appear are to be filled in with the same material as the roadbed, and rolled until the whole becomes uniformly compact and solid.

"Upon the roadbed, thus formed and compacted, shall be deposited a layer of spalls and broken stone—the dimensions of the stone to be as nearly uniform as possible. The stone shall be free from dust and dirt. After being placed in position, this layer shall be thoroughly rolled to a true and even surface; any depressions to be filled up and re-rolled. The layer to be six inches thick after consolidation, and the surface to be parallel to the established cross section and finished surface of the street.

"Gutters are to be paved with mesquite blocks fifteen inches long, three inches thick and five inches deep, resting upon the stone foundation, above specified, with an intermediate layer of fine screened gravel; the blocks laid close and at right angles to the axis of the street.

"The gravel forming the intermediate and surface layers must pass through screens of the following sizes: 1st size—Screens with meshes one-half inch square; 2d size—Screens with meshes two inches square.

"The intermediate layer of gravel to consist of second size screenings, as described above. The layer must be three (3) inches thick after being thoroughly consolidated by the roller. The rolling to begin at the gutter and be gradually worked towards the centre. On its upper surface it must be identical in rise and form to the cross section of the finished surface.

"In laying this course, a small quantity of binding material is to be used, sufficient only to fill up crevices and render this portion of the pavement solid.

"The binding material may be of fine screened gravel or sand, which is to be sufficiently watered during the process of rolling to prevent adherence to the roller.

"On the intermediate course is to be laid the surface layer of gravel. It must be three (3) inches in depth, after being consolidated by rolling.

"This layer is to consist of screenings of the first size, as described above, and to contain no large stones whatever.

"The material is to be raked to an even surface and the roller passed over it two or three times.

"The surface is then to be sprinkled and the rolling continued, working the roller backward and forward gradually from the gutter towards the centre, with an occasional light watering of the pavement and the addition of the necessary material until the cross section is exact according to specification, and the roadway firmly compacted and solid."

The material we have here at hand is a very soft limestone which can be easily worked, and a closely paved foundation can be obtained at moderate expense. The gravel is very hard flint, of irregular shape, and not water worn. The screenings from the gravel which we use for binder consist of small particles of flint and grit, mixed with clay and black soil. The specifications have been very well carried out, with the exception that I have found it better to make the layers of gravel four inches and two inches, and have the top two inches of gravel put through a $\frac{3}{4}$-inch mesh instead of a $\frac{1}{2}$-inch.

Before rolling the middle layer of gravel I have had it well sprinkled, and not rolled until the top had dried enough not to stick to the roller, the rolling being continued on this layer until the stones were well settled in place and did not mount up before the roller. Bare places will appear on the surface caused by the fine binding material sifting down through the stone. No attempt has been made to cover them up. The top two inches has received most of the rolling. After it has been brought to a firm surface, it has been thoroughly wet, in fact flushed, and rolled repeatedly in that condition. The surplus clay and dirt will work to the surface, where it is kept so thin that it will not stick. The result is that all the fine gravel is firmly bedded, and the surface is hard and smooth. As an experiment, I had sand spread over the surface of a small piece while the top was being rolled. I found it to be a great improvement, but it was not kept up on account of the expense. The first piece of work was finished about seven months ago, and since that time it has been subjected to a continual travel, consisting of country wagons, wood wagons and a great deal of light driving.

Although no attention has been paid to it in the way of repairs, there is no showing of ruts or uneven wear as yet.

In a short time I expect to put down a short piece of street with gravel only, leaving out the Telford foundation, when I can compare the results as to duration. I believe, however, for light travel, with a firm soil, that a cheap and durable roadway can be obtained at a small cost, provided the subgrade is thoroughly rolled, and provision made for underdrainage.

The contract price for the Telford work is 76$\frac{1}{2}$c. per sq. yd. of finished surface; excavation, 29$\frac{1}{2}$c. per cu. yard; curbing, 54$\frac{1}{2}$c. per lineal foot; gutter, 27$\frac{1}{2}$c. per lineal foot.

This price, however, is low, and the contractor has lost money. I consider $1 per square yard a fair price for the best workmanship and carefully selected material.

The greater parts of the roads have been built on a black, sticky soil, which when wet gets very soft, and is almost entirely impervious to water. When dry it is very hard, and cracks open. The work is hardly old enough yet to make any very valuable comparisons.

Mr. C. B. Holmes: The Chicago City Railway Company has used wood extensively in paving its tracks, and has used a large variety of it: pine, hemlock, cedar, maple, elm, gum wood and lignum vitæ. The gum wood was in round blocks, and in a short time wore into an oval shape like a saucer inverted, and became so objectionable for horses to travel on we had to take it out. None of the woods lasted for a satisfactory period, and all were very hard on horses. When frozen, the animals would strain all the cords and muscles to retain a foothold on the slippery pavement, and soon became disabled, many of them falling and breaking limbs or otherwise injuring them. In the summer time the case was but little better when the blocks were wet and "greasy." On State street, from Madison to Lake street, the company renewed the pavement regularly every six months, and sometimes it would last only four months; but in my estimation a much more serious objection to wood is the effect on health. Let any person come into the city from the lake or the country, where air is pure, any warm morning in summer, just after a shower, and walk down any street which has been paved for six months with wood, and he can taste the bitter poison in the air which comes from the fermentation and decomposition of the fibres of the wood, saturated with the vilest of excrements and droppings from the horses, and the wind blows these germs of disease into the houses of the people, causing diphtheria and scarlet fever and kindred diseases, which prevail to such an alarming extent in a city paved with wood. Our experience, extending over a long term of years, condemns utterly all kinds of wood pavement, for the reasons given: Short-lived, always out of repair, expensive and very unhealthy. My motto is, *anything but wood.*

The President: Mr. Holmes, what would you recommend for a street pavement?

Mr. Holmes: A good substantial granite block on a business street where heavy trucking is done and in all horse paths of street railways, and in residence streets a macadam foundation, with a good substantial dressing of from three to six inches of crushed granite rolled with a heavy roller, the heavier the better. This secures a clean, permanent, healthy, quiet pavement.

Mr. L. P. Morehouse: By the "best roadway for residence streets" I understand that which is the best or most satisfactory, so far as the residents or property owners are concerned. It is, however, possible that a non-resident owner might be satisfied with a pavement which might be very objectionable to a resident non-owner, and the latter might require a much more expensive pavement than the owner would be willing to pay for, so that I think the question really resolves itself into asking what is the most satisfactory pavement for the resident owner, the man who has to pay for the improvement and its renewal, and to live with his family in daily contact with what may be a great source of comfort or of annoyance. I have often driven over very excellent roads alongside of which I should have been most unwilling to live. To insure a comfortable paved street for its residents, there must be freedom from noise, dust and mud; and to satisfy the property owner, these advantages must be obtained at a reasonable expense. Practically,

therefore, it is impossible to answer the question as it stands, for the "best" pavement costing, say, three dollars a square yard, might be very unsatisfactory to an owner who was only willing to pay fifty cents a yard. Absolute freedom from noise, dust and mud can only be obtained by the expenditure of considerable money; more, in fact, than most owners are willing to spend for this purpose, the majority of people expecting to put up with more or less of discomfort in this matter, as in most others. The asphaltum pavements, either continuous as sheet asphaltum or in blocks, claim the highest excellence in cleanliness and durability, but their high cost, $2.50 to $3.50 per yard, I think forbids their use except upon the best residence streets. I say "forbids their use," as a matter of fact, not, perhaps, of necessity, for their advocates will tell us that the comparatively high first cost is compensated for by their advantages over less durable and desirable pavements. The only objections that I have heard urged against these pavements are the unpleasant clicking of horses' hoofs on them, and their smoothness, which, when they are unsprinkled, allows the dirt tracked on to them to blow off in fine dust. So far as I am aware, the wooden block pavement comes next in its claim for comfort, and has the pecuniary advantage over asphalt in its first cost, which ranges from a dollar to a dollar and a half a yard. Mr. Holmes takes the position that the wood pavement is unhealthy, and states that the odors arising from it after a rain are very unpleasant. Some of our members have been much in favor of this pavement, and I should like to hear from them on these points. Mr. Greeley has laid a great deal of wood pavement in the city, and I presume Mr. Bullard can say what the results thus far are in Springfield, Ill., where the cedar block has been used extensively during the last five or six years. I lived for several years on a street paved with the Nicholson, and found it very satisfactory so far as noise and dust were concerned, so long as the pavement remained in good condition. The street was sprinkled only to a very limited extent, but there was very little annoyance from dust. Waiving the matter of healthfulness, it is a mooted question, however, whether the first cost is enough lower than that of asphaltum to offset the expense and discomfort occasioned by the perishable nature of the material. Let us hear something on this point. How long will the wooden pavement remain in good condition? Ten years—twelve years—fifteen years? Many of us have seen wooden pavements go to pieces in three or four years. But if the wooden block pavement is not unhealthy and will retain an even surface for ten years, with light repairs, it certainly has strong claims for adoption on residence streets. The average owner would probably prefer to renew this once in ten years at a cost half that of asphaltum rather than pay a hundred per cent. more at first for a pavement that would last two or three times as long. If both be unsprinkled, it seems to me that a new block pavement is as free from dust, mud, and noise as the more expensive asphaltum. Now, for how long a time can we maintain this condition for the wood? Can we materially lengthen it by a system of judicious repairs?

With regard to macadam and gravel roads, their character is generally determined by the material most available for the purpose. Mr

Matlack, for his San Antonio streets, appears to be quite fortunate, the stone and gravel working so well together. In many localities the material used is very objectionable on account of the dust, the top dressing and upper layers grinding up, under the traffic, into a fine powder that becomes a most serious annoyance whenever a brisk breeze stirs it up and carries it into the houses of the much suffering residents. It must be admitted, from our standpoint, that such roads are not satisfactory. Particular care should be taken to secure material that will give the minimum of dust. Under the delusion that a road which is satisfactory for driving purposes is necessarily a desirable improvement for the persons residing on it, we find that the average householder accepts such a road as a matter of course, and submits to the rapid deterioration of his furniture and his wife's good nature with a feeling of what he may suppose to be content, but which is really resignation. He will tell you that there is no trouble from dust, as the road is kept well sprinkled; but as this practice is kept up only about half the year, it is plain that, for a considerable portion of the time, there can be no relief. Indeed, the times of the year when the winds are the highest are those when it is impossible to get any sprinkling done. Admitting that a wooden block pavement will accumulate some dirt and produce some dust, and, on the other hand, that we are willing to pay six months in the year for sprinkling a macadam road, I think that the average of dust on the unsprinkled wood paved street would be less than that on the sprinkled macadam. Now we are considering a residence street with a limited amount of travel, which indicates that the street is not built up in continuous blocks, there are unoccupied lots owned by non-residents, and to insure freedom from dust the residents must pay for sprinkling in front of these as well as in front of their own property. The resident owner of fifty feet frontage must then expect to pay at least fifteen dollars annually for this purpose. If the block pavement is more desirable, the owner would be warranted in borrowing $100, payable at the end of ten years, at 5 per cent. annual interest, for the yearly amount of fifteen dollars would put aside one-tenth of the principal and pay the interest. If the roadway were 36 feet wide, the fifty feet would have to pay for 100 square yards, so that on this basis the owner could afford to pay a dollar a yard more for the block than for the macadam. But if the element of dust can be eliminated from the macadam or gravel road, we ought to obtain the most satisfactory road, for the first cost, and the maintenance should be less, and the durability much greater than that of the wood pavement. My personal experience with the former is that they are very objectionable on account of the dust.

I should like to hear from others on this point. Mr. Powell has put a top dressing of crushed granite on some streets in Hyde Park, and, perhaps, he can tell us if this obviates the evil. The ordinary macadamized streets in Hyde Park are very dusty, except when well wet down.

Mr. Matlack thinks that his road should cost about a dollar a yard, and this, I believe, is about the cost of macadam roads put down in and about Chicago. For many localities, however, it is necessary to have a cheaper road than this. There are places where non-resident owners are unwill-

ing, and cannot be obliged to incur any expense, and the residents are, under the circumstances, willing to do all the work if it can be done very cheaply ; or the tracts may have a large frontage, requiring a large expense for each owner, even at the minimum cost per yard or lineal foot. What will you give us for these ?

The ordinary macadam road has a foundation of large stones, the successive layers growing smaller and smaller, but I have noticed excellent roads, or rather short sections, which had been made simply by the deposit of house ashes, year after year, in the sand of the highway in front of the houses. Having occasion to excavate through one of these sections, I found the material almost as hard as rock. Will some one tell us if the solidification is due to the union of the sand with the ashes, or will the ashes of themselves, under pressure, bind sufficiently to make a compact mass suitable for a roadway? In other words, can you by means of a heavy roller make a good road of house ashes alone?

Rolling-mill cinders are used locally to some extent for roads, but I should think that, perhaps, house ashes mixed with them might be an improvement. Can any one speak as to this?

The subject opened up by the query is a pretty broad one, but, perhaps, the discussion of cheap suburban roads is the most important part of it.

Mr. S. A. Bullard : A pavement for a street must be (a) serviceable, (b) economical, (c) inoffensive, in order to be satisfactory to those who use or pay for it. Opinions are generally based on an examination from one or other of these standpoints and necessarily result in a wide difference of opinions. The truckman judges of a pavement from the service he gets out of it, the ease or difficulty with which he hauls his loads ; the taxpayer from the points of cost and durability ; the resident from the convenience or inconvenience he enjoys or endures ; the physician from the effects it has upon the health of his patients and patrons ; and public opinion we know to be a jargon with a sound for every one of the multitudinous business affairs of man. Probably no one pavement will fill the requirements of being serviceable, economical and inoffensive, though some approximate nearer than others to them.

Serviceable.—A pavement for the street under discussion should be of a firm, smooth, regular surface, not entirely unyielding, such as asphalt wood block or burned clay.

Economical.—The pavement should be of such first cost as not to be an overburden to the property owner. The pavement that is to be often renewed may not be necessarily an extravagant one. A pavement costing $1.50 per yard, and requiring renewal every ten years, is more economical than one costing three dollars per yard with renewal every thirty years. That is, the interest on the difference of cost of the two pavements will pay the renewal of the cheaper one. There would be a period in the life of either pavement of inconvenience, just before renewal, when the pavement would be poor, but a further comparison is extremely unfavorable to the longer lived pavement, inasmuch as the cost of its renewal is an entirely new outlay. I should think that for the street under discussion the cheaper pavement would be the most desirable, unless it lay in a wealthy city or suburb where the property owners

were in circumstances enabling them to consult their taste rather than their purse in the contemplated improvement. However, I have never yet seen a whole street owned by that class of people, though individuals of that class are not infrequently met.

The economical pavement is one having moderately lasting qualities, and having a correspondingly moderate cost.

Inoffensiveness.—Pavements give offense (a) by the presence of disease-producing germs, (b) making or wearing into dust, (c) giving rise to noise in the passage of vehicles. The first source of offense is most serious and should never be overlooked. When a pavement produces or distributes disease germs it should be at once removed as a public nuisance. The second source—the wear of a pavement—the wear should never be so rapid as to make the accumulation of dust or dirt on the street from that cause perceptible. The tracking of dirt or mud on pavements will probably be as great on one as on another. The third source is determined by the smoothness of the surface and the yielding qualities of the materials. Now what pavement or pavements under the light of these statements would be most acceptable to impartial and disinterested parties acting as judges?

Let us place them before us in a tabulated form :

(A.) Granite block pavement. Service—Reasonably good. Economy—High cost, but long lived. Inoffensiveness—Noisy, some dust, healthful.

(B.) Macadam with limestone surface. Service—Acceptable. Economy—Moderate cost, but needing constant repairs. Inoffensiveness—Little noise, dust intolerable, healthful.

(C.) Macadam, with crushed granite surface. Service—Acceptable. Economy—Expensive. Inoffensiveness—Little noise, dust tolerable, healthful.

(D.) Asphaltum. Service—Very good. Economy—High cost, but not long lived in this climate. Inoffensiveness—Little noise, no dust, healthful.

(E.) Wood block. Service—Very good. Economy—Moderate cost, medium life. Inoffensiveness—Little noise, no dust, healthful, except last year or two.

(F.) Burned clay blocks. Service—Very good. Economy—Moderate cost, long life. Inoffensiveness—Little noise, little dust, healthful.

As the granite block, macadam, and asphaltum pavements would be expensive on account of first cost, the only pavements I think we should consider as suitable for the street under discussion would be wood block, or tile, or burned clay. If stone is so near the street to be paved that freight will be trifling, then macadam pavement would not much exceed in cost that of wood block or burned clay. Gravel streets I have not considered, because of the impossibility to keep them clean at cross unpaved streets in our soil. In removing the accumulated earth the surface of the pavement is disturbed, and rapid disintegration takes place, requiring expensive repairs.

The wood block pavement will not wear out on the street under discussion before it will have to be replaced on account of decay. The white cedar block, of which we have laid a great deal in Springfield, has a life on an average of ten years without expensive repairs before renewal.

The first cost of pavement is about $1.35 per yard, everything included It can be replaced at $1.20 per yard, the excavation not having to be done. The effects of the cedar block pavement on the health of the community is not at all injurious until decay has reduced the blocks in places to a mass. Then it is bad and should be condemned and ordered removed. The pavement, for two years before renewal, could not be called a good pavement for traffic or light travel, and is certainly not conducive to the good health of the residents thereon. It is not a pavement, therefore, without objections, and cannot be fully recommended for the street under consideration.

The burned clay pavement has many qualities very commendable. The noise is comparatively nothing, the pieces are so evenly joined that friction or attrition is trifling. The pavement presents an even surface and stands travel and wear well. The cost is not much in excess of the white cedar block, being about $1.60 per yard complete. There is no decay. The healthfulness of it is unquestioned, being such as granite or macadam pavements, and the durability will certainly reach twenty or more years if the pavement be made a piece of the shape of common brick, but if made in forms more suitable for paving would last much longer.

I should think that for a residence street having little heavy travel, a burned clay pavement is much to be preferred to any other, considering the service required, economy and the inoffensiveness of the pavement.

Another advantage burned clay has as a paving material is that it can be produced in almost every locality, while stone, cedar blocks and asphaltum have to be shipped long distances. The advantage would be local only, and though the city or community in which the street is would be helped by the additional business of making and producing the paving materials, that would perhaps be of no financial consequence to the property owners who pay for the pavement.

When cities have experimented sufficiently with burned clay pavements and proved they may be produced and laid in any locality using local labor and capital entirely in their production then will they come into much more popular favor and the paving interests of smaller cities will be greatly advanced thereby.

Mr. L. P. Morehouse : Brick pavements are coming into considerable use in the towns of Central Illinois. The city of Bloomington, I think, was the pioneer. I am informed that streets laid there ten years ago are still in first-rate condition. In the city of Decatur I noticed, a few days ago, that some of the principal streets are being paved with bricks. Mr. Burgess, city engineer, is laying these pavements under the following specifications :

"Said street for a distance of .... feet, on each side of the central line thereof, shall be excavated to the depth of 12 inches, along the central line thereof below the established grade thereof, and at the outer edges of said street, where the same is so excavated, on either side thereof at a distance of .... inches toward the centre of said street, respectively, to the depth of .... inches, the said excavation of said street to be in the form of a segment of a circle. The portion of said street,

between said .... inch lines, aforesaid, and the outer edges of said street so excavated, on both sides thereof, shall be so graded and paved in a similar manner as the balance of said street, so as to make a good and substantial gutter along said .... inch lines; and when said street shall have been so excavated, there shall be placed thereon a bed of sand and gravel 4 inches in depth, said sand and gravel to be well tamped so as to form a smooth and compact surface; and on said bed of sand and gravel, so tamped and made smooth, shall be laid on their flat surface, a close floor of hard burned, sound, and shapely paving brick, said brick to be laid longitudinally with the street, and the joints broken in each course; said brick to be put closely together so as to form a smooth and solid floor, no broken or cracked brick to be used; over said floor of brick so laid there shall be placed a layer of screened sand .... inch in thickness, so as to fill all crevices, and made smooth, so as to form an even floor for the subsequent layer of brick; upon said layer of sand so made smooth, there shall be placed and laid on their edges, in close contact with each other, a layer of extra hard burned paving brick, said brick to be laid at right angles with the line of said street, joints to be broken in each alternate course, all brick being sound and of full size; after said bricks are so laid a thin layer of screened dry sand shall be swept over said pavement so as to fill all crevices therein, after which a top dressing of clean unscreened gravel, not less than 1 inch in depth, shall be placed over the entire surface of said improvement. There shall be two cross-walks at the intersection of each street, one on each side, so as to connect with the sidewalks, of the width of 6 feet, to be formed by an oval elevation across said street, so that the centre of each cross-walk will be 4 inches below the grade of the sidewalk with which they connect, and slope to meet the grade of the street, and to extend to a point within 4 feet of the outer edges of said improvement, so that aprons may be placed over the gutters."

I am in hopes that Mr. Bell, of Bloomington, will let us hear from him on this question.

Professor I. O. Baker: In Champaign we have used the brick pavement for about three years, and they give excellent satisfaction.

Mr. A. H. Bell: The question as to the most suitable material for street paving in various localities is one which is the concern of municipalities in all sections of the country. So far as the city of Bloomington, Ill., is concerned, this question is at rest. We have tried stone blocks, Nicholson and macadam pavements, and still have samples of each from which to draw our conclusions; but the citizens of Bloomington are a unit in favor of brick for future street pavements. The reasons for this are cost, durability, lack of noise and general satisfaction, to which might be added the fact that we produce the brick at home, thus patronizing home industry and avoiding freights. The first piece of brick pavement was laid here about nine years ago, on the west side of the Court House Square. It was laid under the general specifications which will be given later on, and is still down and in very good condition, having had but very slight repairs, where excavations were made for sewerage or other purposes. Last year there were laid about 9,000 yards of brick pavement; this year we have laid probably 12,000 yards. It

presents a very desirable surface, and gives universal satisfaction. No complaints are brought against the use of brick for pavements, so far as our experience goes. The pavement is easily kept clean, easily repaired, or removed for excavation purposes; it is noiseless and pleasant to drive over if properly laid. What was laid during the present year in Bloomington cost $1.15 per square yard for the brick and the laying of the same in the pavement. The city did all grading, and furnished all necessary sand or cinders. The entire pavement, including *all material*, grading of lawns, etc., also stone curbing (4 inches by 30 inches), cost $2 per square yard. The best paving brick in this locality are quoted at $10 per M. Laborers cost $1.60 per day, teams $3.25, and sand costs 80@90c. per cubic yard delivered on the work. In the business portion of the city we are paving the entire street between sidewalks; in the residence portion we pave from 30 to 36 feet in width, leaving the balance of the street for sidewalks and lawns. The cross section of the pavement is in the shape of an arc, with a rise of 6 inches in the centre (for 36 feet width), and the stone curbing 1 inch above the centre of the pavement, thus exposing 7 inches of stone to view. The drainage is provided for by means of inlets through the stone curbing into sewer pipes leading into the main sewer, similar to the system used at Springfield, Ill. The general construction of our brick pavements is as follows: The foundation, being brought as nearly to the proper grade and shape as possible, is thoroughly rolled with a roller weighing at least two tons (the stone curbing of course being previously set.) There is then spread over the whole a course of about 2 inches of cinders, (gravel would do as well I presume,) which is *thoroughly rolled and compacted*, care being taken at all times to retain the uniform shape and grade. This course of cinders should be rolled until it is *very compact* and hard, and great care should be exercised to have it in the exact shape and form desired for the surface of the pavement. Upon this cinder bed so prepared is placed a course of 2 inches of sand. This is carefully gauged by means of boards having the proper convexity, and is the final course for receiving the brick. A course of bricks is now laid on their flat surface, the longest dimensions being in the direction of the street and care being taken to break the joints. It is not necessary that the bricks in this course should be as hard and tough as those in the upper layer, as they do not receive the traffic, but only fulfill the purpose of a foundation for the *upper course* of bricks, which must be of the hardest and toughest that can be procured. Having so placed a course of bricks upon their flat surface, and covered the same with an inch of screened sand, the upper or final layer is laid across the street upon their longest 2-inch surface; care being taken to break joints as before, and to place the convex edge of the brick up, where any convexity exists. The whole is then covered with sand (screened), which is continuously swept into the crevices and rolled with a heavy roller (not less than 2 tons being of much service.)

This final rolling is of much importance and will render the surface of the pavement as good as any Nicholson or wooden block pavement I have ever seen laid, if the other precautions mentioned are observed, and the bricks have any degree of uniformity. I am a strong advocate of brick

pavements in those sections of the country where a suitable article of brick can be obtained. The durability of the pavement will depend much upon the quality of the material. The bricks should be very hard burnt, almost vitrified, particularly the upper course. Toughness and tenacity are the desirable qualifications to secure durability. I am not prepared to state how these pavements would stand in the streets of large cities, where they would be subjected to very heavy traffic, but even there I believe they would surprise the profession if constructed with proper care.

There is so much dependent upon the manner in which a brick pavement is constructed, that the article has scarcely had a fair trial in this country as yet. We have one street paved in Bloomington, running from the Union Depot to the Court House, over which there is a great deal of heavy traffic, nearly all the coal used in the city being carried over this pavement, besides a great deal of heavy hauling of a general character. This street was paved early last year and shows no appreciable signs of wear as yet. Of course its life has been short, but if the brick were going to yield to heavy traffic, sufficient time has elapsed to give some indications, which are not visible. The heaviest grade we have yet laid brick on is that of 4 feet to the 100 feet. We have experienced no trouble from slipping and I believe they could be satisfactorily laid on much heavier grades.

Mr. Wright: I have had no experience with brick pavements, and should favor round cedar blocks for such a street, having a light traffic. Such a pavement has been laid in Chicago for 97c. per square yard. It is cheap in first cost and durable under the above conditions. When the traffic is heavy it will last only a short time. It does not wear as well as pine blocks of average quality, and in the down town tracks of the North Chicago City Railway new pine block pavement was worn within six months, requiring repairs and within eleven months an inch and a half had worn off, and the entire pavement had to be replaced.

The durability of wooden pavements depends upon the amount of traffic, upon the soundness of the wood used, upon the kind of wood, upon the season of year at which it is felled, upon the seasoning of the timber, upon the foundation, upon the care and thoroughness with which it is laid, and upon the condition in which the surface of the pavement is maintained.

The sprinkling of the street has much to do with the durability of the wood pavement. I have seen adjacent pieces of pavement where part was thoroughly sprinkled several times daily, remain sound and free from decay at least three times as long as that unsprinkled. Cedar block pavement between the tracks of the North Chicago City Railway (*not* in horse paths) was comparatively sound at the expiration of ten years.

The cedar block pavement, possessing the advantages of noiselessness, cheapness, and durability, would be my preference for a suburban street with light traffic; but the blocks should all be sound, well and thoroughly laid and rammed, and the pavement sprinkled and cleaned.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

BOSTON, November 17, 1886:—A regular meeting of the Boston Society of Civil Engineers was held and called to order at 7:30 P. M., President G. L. Vose in the chair, thirty-four Members and five visitors present. The record of the last meeting was read and approved.

Messrs. George Alexander, N. Henry Crafts, Joseph R. Worcester, were elected members of this Society.

Mr. George S. Morrill was proposed for membership, recommended by H. Manley, E. W. Howe.

A memorial on the death of Mr. Ellis Sylvester Chesbrough, prepared by the committee, E. C. Clarke, T. W. Davis, W. H. Bradley, was read by the Secretary. Professor G. F. Swain read a memorial on the death of Professor William Ripley Nichols.

A communication from the American Society of Civil Engineers was read, requesting an expression of opinion from this Society on the matter of proposed changes in the organization of the American Society in connection with the subject of local societies and of sections or chapters of that Society. On motion it was voted: That a committee of five, two to be Members of the American Society be appointed by the President to consider the communication from the American Society and report at the next regular meeting. The President appointed a committee consisting of F. P. Stearns, W. S. Chaplin, J. E. Cheney, W. E. McClintock, H. A. Carson.

Mr. J. A. Tilden read a paper on Water-Meters.

Professor G. F. Swain explained some new points in the calculation of bridges.

[*Adjourned.*] H. L. EATON, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

NOVEMBER 17, 1886:—The Club met at 8:10 P. M., President McMath in the chair; sixteen Members and two visitors present.

The minutes of last meeting were read and approved.

The proceedings of the meeting of the Executive Committee on October 30 were reported to the Club. The Executive Committee reported the following programme for the year:

Nov. 17. Professor J. B. Johnson, Earthwork Computations by the Prismoidal Formula.

Dec. 1. Chas. F. White, Some Tests of Furnace Efficiency. Annual meeting and reports of officers.

Dec. 15. Prof. F. E. Nipher, Economic Co-efficient of the Shunt Dynamo. Announcement of result of letter ballot for officers.

Jan. 5. Prof. H. S. Pritchett, Result of Mexican Longitude Determinations. T. T. Johnson, Discussion of Discharge Measurements in Tunnels under Varying Heads.

Jan. 19. Dr. Wellington Adams, The Construction of Dynamo-Electric Machinery.

Feb. 2. E. D. Meier, Evaporative Efficiency of Boilers.

Feb. 16. Robert Moore, Water-way for Railroad Culverts.

March 2. E. E. Furney, Compound Oscillating Engines.

March 16. Edward Flad, Oscillations of Water in Stand-Pipes.

April 6. Dr. C. M. Woodward, Gas Producers for Ordinary Boilers.

April 20. C. W. Clark, Experiments on Submerged Adjutages. D. E. Condon, Experimental Studies Relating to Water Supply.

May 4. J. W. Hill, J. T. Monell.

May 18. H. A. Wheeler, Relative Economy of Machine and Hand Drilling. Chas. W Melcher.

June 1. Report of Committee on Smoke Prevention, Prof. W. B. Potter, Chairman.

On motion the report was adopted.

The applications of Otis Breden, Chas. W. Bryan, Benj. F. Crow, and Wm. L. Seddon, for membership, were read and laid before the Executive Committee.

The Secretary read a communication from the American Society of Civil Engineers on the subject of changes in the organization of that body, and inviting a written communication from the Club on that subject.

On motion it was decided to refer the letter to a committee of five, a majority not to be members of the American Society of Civil Engineers.

The Chair appointed on this committee: J. B. Johnson, H. W. Baker, F. H. Pond, Wm. Bouton and Robert Moore.

The Chair stated reasons for delay in filling the vacancy in the Committee on Smoke Prevention.

The Special Order of the evening, a paper by Prof. J. B. Johnson, was then taken up.

The Chair called attention to the fact that arrangements should be made for the annual meeting on Dec. 1.

On motion it was decided that a committee of five on nominations of officers be elected by ballot. The balloting resulted in the election of the following committee: S. B. Russell, Robt. Moore, Chas. W. Melcher, T. J. Whitman, Wm. Bouton.

[*Adjourned.*] Wm. H. Bryan, Secretary.

WESTERN SOCIETY OF ENGINEERS.

November 2, 1886:—The 230th meeting was held at 7:30 p. m., President Wright in the chair.

The minutes of the preceding meeting were read and approved.

Applications to be admitted to membership were received from Mr. C. F. Carl Binder, Civil Engineer, with W. G. Coolidge & Co., Chicago; Mr. Bernhard Feind, Assistant Engineer Drainage and Water Supply Commission, City Hall, Chicago; Mr. John Wilson, Engineer North Chicago Cable System, 86 Lincoln avenue, Chicago.

Mr. Arthur H. Bell, City Engineer of Bloomington, Ill., was elected a Member.

The Secretary read a paper on "Street Pavements of Brick," by Mr. A. H. Bell.

A circular letter from the American Society of Civil Engineers was read, asking communications from this and other engineering societies on the subject of changes in the organization of the American Society. It was understood that the changes had reference to an organic union of the other societies with the American Society, and it was voted that consideration of this matter should be made the special business of the next meeting.

[*Adjourned.*] L. P. Morehouse, Secretary.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

SEPTEMBER 28, 1886 :—Special meeting held. President Latimer in the chair.

A letter was read from Mr. Barbot, City Engineer of Charleston, S. C., to Mr. Latimer, giving a graphic description of the recent earthquake, and inclosing specimens of sand thrown up by volcanic action.

Mr. J. D. Varney read a paper entitled "A Review of the Practice of Surveying in this Country." A general description of the paper followed.

Mr. Latimer gave some of his recent experiences with the "dip needle."

[*Adjourned.*] C. M. BARBER, Recording Secretary.

OCTOBER 12, 1886 :—Regular meeting held. President Latimer in the chair.

Minutes of the last two meetings were read and approved.

Mr. Rawson called the attention of the Club to the fact that the election of Professor Michelson had not been in accordance with the rules of the Club, and that the matter might be corrected. Upon Mr. Rawson's motion, it was referred to the Committee on Membership.

A letter was read from the Technical Society of Chicago, asking for a list of Members; also a letter from a society in Germany. Both were referred to the Corresponding Secretary for answer.

A book entitled "Selected Papers of the Rensselaer Society of Engineers of New York" was received.

Mr. W. H. Searles read a paper entitled "Cable Railways." Discussion of the paper followed.

[*Adjourned.*] C. M. BARBER, Recording Secretary.

OCTOBER 26, 1886 :—Special meeting held; in the absence of the President, Vice-President Swasey in the chair.

The report of the Committee on Railroad Engineering was in order; but no member of that Committee being present, no report was made.

The Chair read an article on Steel Ties, which, with the fall of the water tower at Gravesend, formed the basis of the discussion for the evening.

Upon motion of Mr. Rawson, the Chair appointed Messrs. Holloway, Whitelaw and Hyde a committee to prepare and present to the Club appropriate resolutions upon the death of Col. Charles Whittlesey, the first Honorary Member of the Club.

[*Adjourned*]. C. M. BARBER, Recording Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

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GEORGE W. WHISTLER, C. E.

BY PROF. G. L. VOSE, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read September 15, 1886.]

Few persons, even among those best acquainted with our modern railroad system, are aware of the early struggles of the men to whose foresight, energy and skill the new mode of transportation owes its introduction into this country. The railroad problem in the United States was quite a different one from that in Europe. Had we simply copied the railways of England we should have ruined the system at the outset, for this country. In England, where the railroad had its origin, money was plenty, the land was densely populated, and the demand for rapid and cheap transportation already existed. A great many short lines connecting the great centres of industry were required, and for the construction of such in the most substantial manner the money was easily obtained. In America, on the contrary, a land of enormous extent almost entirely undeveloped, but of great possibilities, lines of hundreds and even thousands of miles in extent were to be made, to connect cities as yet unborn, and to accommodate a future traffic of which no one could possibly foresee the amount. Money was scarce, and in many districts the natural obstacles to be overcome were infinitely greater than any which had presented themselves to European engineers.

By the sound practical sense and the unconquerable will of George Stephenson, the numerous inventions which together make up the locomotive engine had been collected into a machine, which, in combination with the improved roadway, was to revolutionize the transportation of the world. The railroad, as a machine, was invented. It remained to apply the new invention in such a manner as to make it a success and not a failure. To do this in a new country like America required infinite skill, unbounded energy, the most careful study of local conditions, and the exercise of well matured, sound business judgment. To see how well the great invention has been applied in the United States we have only to look at the network of iron roads which now reaches from the Great Lakes to the Gulf of Mexico, and from the Atlantic to the Pacific.

With all the experience we have had, it is not an easy problem, even at

the present time, to determine how much money we are authorized to spend upon the construction of a given railroad. To secure the utmost benefit at the least outlay, regarding both the first cost of building the road and the perpetual cost of operating it, is the railroad problem which is perhaps less understood at the present day than any other. It was an equally important problem fifty years ago, and certainly not less difficult at that time. It was the fathers of the railroad system in the United States who first perceived the importance of this problem, and who, adapting themselves to the new conditions presented in this country, undertook to solve it. Among the pioneers in this branch of engineering no one has done more to establish correct methods, nor has left behind a more enviable or more enduring fame than Major George W. Whistler.

The Whistler family is of English origin, and is found toward the end of the 15th century in Oxfordshire, at Goring and Whitchurch, on the Thames. One branch of the family settled in Sussex, at Hastings and Battle, being connected by marriage with the Websters of Battle Abbey, in which neighborhood some of the family still live. Another branch lived in Essex, from which came Dr. Daniel Whistler, President of the College of Physicians in London in the time of Charles the Second. From the Oxfordshire branch came Ralph, son of Hugh Whistler, of Goring, who went to Ireland, and there founded the Irish branch of the family, being the original tenant of a large tract of country in Ulster, under one of the guilds or public companies of the city of London. From this branch of the family came Major John Whistler, father of the distinguished engineer, and the first representative of the family in America. It is stated that in some youthful freak he ran away and enlisted in the British Army. It is certain that he came to this country during the Revolutionary War, under General Burgoyne, and remained with his command until its surrender at Saratoga, when he was taken prisoner of war. Upon his return to England he was honorably discharged, and, soon after, forming an attachment for a daughter of Sir Edward Bishop, a friend of his father, he eloped with her, and came to this country, settling at Hagerstown, in Maryland. He soon after entered the army of the United States, and served in the ranks, being severely wounded in the disastrous campaign against the Indians under Major General St. Clair in the year 1791. He was afterward commissioned as lieutenant, rose to the rank of captain, and later had the brevet of major. At the reduction of the army in 1815, having already two sons in the service, he was not retained; but in recognition of his honorable record, he was appointed Military Storekeeper at Newport, Kentucky, from which post he was afterward transferred to Jefferson Barracks, where he lived to a good old age.

Major John Whistler had a large family of sons and daughters, among whom we may note particularly William, who became a colonel in the United States Army, and who died at Newport, Ky., in 1863; John, a lieutenant in the army, who died of wounds received in the battle of Maguago, near Detroit, in 1812; and George Washington, the subject of our sketch. Major John Whistler was not only a good soldier, and highly esteemed for his military services, but was also a man of refined tastes and well educated, being an uncommonly good linguist and espe-

cially noted as a fine musician. In his family he is stated to have united firmness with tenderness, and to have impressed upon his children the importance of a faithful and thorough performance of duty in whatever position they should be placed.

George Washington Whistler, the youngest son of Major John Whistler, was born on the 19th of May in the year 1800 at Fort Wayne in the present State of Indiana, but then part of the Northwest Territory, his father being at the time in command of that post. Of the boyhood of Whistler, we have no record, except that he followed his parents from one military station to another, receiving his early education for the most part at Newport, Ky., from which place, on July 31, 1814, he was appointed a cadet to the United States Military Academy, being then fourteen years of age.

The course of the student at West Point was a very satisfactory one. Owing to a change in the arrangement of classes after his entrance, he had the advantage of a longer term than had been given to those who preceded him, remaining five years under instruction. His record during his student life was good throughout. In a class of thirty members he stood No. 1 in drawing, No. 4 in descriptive geometry, No. 5 in drill, No. 11 in philosophy and in engineering, No. 12 in mathematics and No. 10 in general merit. He was remarkable, says one who knew him at this time, for his frank and open manner and for his pleasant and cheerful disposition. A good story is told of the young cadet which shows his ability, even at this time, to make the best of circumstances apparently untoward, and to turn to his advantage his surroundings, whatever they might be. Having been for some slight breach of discipline required to bestride a gun in the campus for a short time, he saw, to his dismay, coming down the walk the beautiful daughter of Dr. Foster Swift, a young lady who, visiting West Point, had taken the hearts of the cadets by storm, and who, little as he may at the time have dreamed it, was destined to become his future wife. Pulling out his handkerchief he bent over his gun, and appeared absorbed in cleaning the most inaccessible parts of it with such vigor as to be entirely unaware that any one was passing; nor did the young lady dream that a case of discipline had been before her until in after years, when on a visit to West Point an explanation was made to her by her husband.

It was at this time of his life that the refinement and taste for which Major Whistler was ever after noted began to show itself. An accomplished scientific musician and performer, he gained a reputation in this direction beyond that of a mere amateur, and scarcely below that of the professionals of the day. His *sobriquet* of "Pipes," which his skill upon the flute at this time gave him, adhered to him through life among his intimates in the army. His skill with the pencil, too, was something phenomenal, and would, had not more serious duties prevented, made him as noted an artist as he was an engineer. Fortunately for the world this talent descended to one of his sons, and in his hands has had full development. These tastes in Major Whistler appeared to be less the results of study than the spontaneous outgrowth of a refined and delicate organization, and so far constitutional with him that they seemed to tinge his entire character. They continued to be developed till past the meridian of life, and amid all the pressure of graver duties furnished a most delightful relaxation.

Upon completing his course at the Military Academy he was graduated, July 1, 1819, and appointed second lieutenant in the corps of artillery. From this date until 1821 he served part of the time on topographical duty, and part of the time he was in garrison at Fort Columbus. From November 2, 1821, to April 30. 1822, he was assistant professor at the Military Academy, a position for which his attainments in descriptive geometry and his skill in drawing especially fitted him. This employment, however, was not altogether to his taste. He was too much of an artist to wish to confine himself to the mechanical methods needed in the training of engineering students. In 1822, although belonging to the artillery, he was detailed on topographical duty under Major (afterwards Colonel) Abert, and was connected with the commission employed in tracing the international boundary between Lake Superior and the Lake of the Woods. This work continued four years, from 1822 to 1826, and subsequent duties in the cabinet of the commission employed nearly two years more. The field service of this engagement was anything but light work, much of it being performed in the depth of winter with a temperature fifty degrees below zero. The principal food of the party was tallow and some other substance, which was warmed over a fire on stopping at night. The snow was then removed to a sufficient depth for a bed, and the party wrapped one another up in their buffalo robes, until the last man's turn came, when he had to wrap himself up the best he could. In the morning, after warming their food and eating, the remainder was allowed to harden in the pan, after which it was carried on the backs of men to the next stopping place. The work was all done upon snow-shoes, and occasionally a man became so blinded by the glare of the sun upon the snow that he had to be led by a rope.

Upon the 1st of June, 1821, Whistler was made second lieutenant in the First Artillery, in the re-organized army ; on the 16th of August, 1821, he was transferred to the Second Artillery, and on the 16th of August, 1829, he was made fiirst lieutenant. Although belonging to the artillery, he was assigned to topographical duty almost continually until December 31st, 1833, when he resigned his position in the army. A large part of his time during this period was spent in making surveys, plans and estimates for public works, not merely those needed by the National Government, but others which were undertaken by chartered companies in different parts of the United States. There were at that time very few educated engineers in the country, beside the graduates of the Military Academy ; and the army engineers were thus frequently applied for, and for several years government granted their services.

Prominent among the early works of internal improvement was the Baltimore & Ohio Railroad, and the managers of this undertaking had been successful in obtaining the services of several officers who were then eminent, or who afterwards became so. The names of Dr. Howard, who, though not a military man, was attached to the Corps of Engineers, of Lieut.-Col. Long, and of Capt. William Gibbs McNeill appear in the proceedings of the company as "Chiefs of Brigade," and those of Fessenden, Gwynne and Trimble among the assistants.

In October, 1828, this company made a special request for the services of Lieutenant Whistler. The directors had resolved on sending a depu-

tation to England to examine the railroads of that country, and Jonathan Knight, William Gibbs McNeill and George W. Whistler were selected for this duty. They were also accompanied by Ross Winans, whose fame and fortune together with those of his sons, became so widely known afterwards in connection with the great Russian railway. Lieutenant Whistler, says one who knew him well, was chosen for this service on account of his remarkable thoroughness in all the details of his profession, as well as for his superior qualifications in other respects. The party left this country in November, 1828, and returned in May, 1829.

In the course of the following year the organization of the Baltimore & Ohio Railroad, a part of which had already been constructed under the immediate personal supervision of Lieutenant Whistler, assumed a more permanent form, and allowed the military engineers to be transferred to other undertakings of a similar character. Accordingly, in June, 1830, Captain McNeill and Lieutenant Whistler were sent to the Baltimore & Susqehanna Railroad, for which they made the preliminary surveys and a definite location, and upon which they remained until about twenty miles were completed, when a lack of funds caused a temporary suspension of the work. In the latter part of 1831 Whistler went to New Jersey to aid in the construction of the Paterson & Hudson River Railroad (now a part of the Erie Railway). Upon this work he remained until 1833, at which time he moved to Connecticut to take charge of the location of the railroad from Providence to Stonington, a line which had been proposed as an extension of that already in process of construction from Boston to Providence.

In this year, December 31, 1833, Lieut. Whistler resigned his commission in the army, and this not so much from choice as from a sense of duty. Hitherto his work as an engineer appears to have been more an employment than a vocation. He carried on his undertakings diligently, as it was his nature to do, but without much anxiety or enthusiasm; and he was satisfied in meeting difficulties as they came up, with a sufficient solution. Henceforward he handled his profession from a love of it. He labored that his resources against the difficulties of matter and space should be overabundant, and if he had before been content with the sure-footed facts of observation, he now added the luminous aid of study. How luminous and how sure these combined became, his later works show best.

In 1834 Mr. Whistler accepted the position of engineer to the proprietors of locks and canals at Lowell. This position gave him among other things the direction of the machine shops which had been made principally for the construction of locomotive engines. The Boston & Lowell Railroad, which at this time was in process of construction, had imported a locomotive from the works of George and Robert Stephenson, at Newcastle, and this engine was to be reproduced, not only for the use of the Lowell road, but for other railways as well, and to this work Major Whistler gave a large part of his time from 1834 to 1837. The making of these engines illustrated those features in his character which then and ever after were of the utmost value to those he served. It showed the self-denial with which he excluded any novelties of his own, the caution with which he admitted those of others, and the

judgment which he exercised in selecting and combining the most meritorious of existing arrangements. The preference which he showed for what was simple and had been tried did not arise from a want of originality, as he had abundant occasion to show during the whole of his engineering life. He was, indeed, uncommonly fertile in expedients, as all who knew him testify, and the greater the demand upon his originality the higher did he rise to meet the occasion. The time spent in Lowell was not only to the great advantage of the company, but it increased also his own stores of mechanical knowledge, and in a direction, too, which in later years was of especial value to him.

In 1837 the condition of the Stonington Railroad became such as to demand the continual presence and attention of the engineer. Mr. Whistler therefore moved to Stonington, a place to which he became much attached, and to which he seems during all of his wanderings to have looked with a view of making it finally his home. While engaged upon the above road he was consulted in regard to many other undertakings in different parts of the country, and prominent among these was the Western Railroad of Massachusetts.

This great work, remarkable for the boldness of its engineering, was to run from Worcester through Springfield and Pittsfield to Albany. To surmount the high lands dividing the waters of the Connecticut from those of the Hudson called for engineering, cautious and skillful, as well as heroic. The line from Worcester to Springfield, though apparently much less formidable, and to one who now rides over the road showing no very marked features, demanded hardly less study, as many as twelve several routes having been examined between Worcester and Brookfield. To undertake the solution of a problem of so much importance required the best of engineering talent, and we find associated on this work the names of three men, who, in the early railroad enterprises of this country stood deservedly in the front rank: George W. Whistler, William Gibbs McNeill, and William H. Swift. McNeill had graduated from the Military Academy in 1817, and rose to the rank of major in the Topographical Engineers. Like Whistler, he had been detailed to take charge of the design and construction of many works of internal improvement not under the direction of the General Government. These two engineers exercised an influence throughout the country for many years much greater than that of any others. Indeed there were very few works of importance undertaken at that time in connection with which their names do not appear. This alliance was further cemented by the marriage between Whistler and McNeill's sister. Capt. William H. Swift had also graduated from the Military Academy, and had already shown marked ability as an engineer. Such were the men who undertook the location and construction of the railroad which was to surmount the highlands between the Connecticut and the Hudson, and to connect Boston with the Great West.

The early reports of these engineers to the directors of the Western Railroad show an exceedingly thorough appreciation of the complex problem presented to them, and a much better understanding of the principles involved in establishing the route than seems to have been shown in many far more recent works. In these early reports made in

1836 and 1837, we find elaborate discussions as to the power of the locomotive engine, and a recognition of the fact that in comparing different lines we must regard the *plan* as well as the *profile*, " as the resistance from curves on a level road may even exceed that produced by gravity on an incline ;" and in one place we find the ascents " *equated* at 18 feet, the slope which requires double the power needed on a level road," resulting in a " *virtual increase*." We find also a very clear expression of the fact that an increased expenditure in the power needed to operate the completed road may overbalance a considerable saving in first cost. To bear this principle in mind, and at the same time to work in accordance with the directors' ideas of economy, in a country where the railroad was regarded very largely as an experiment, was by no means an easy task. The temptation to make the first cost low at the expense of the quality of the road in running up the valley of Westfield River was very great, and the directors were at one time very strongly urged to make an exceedingly narrow and crooked road west of Springfield ; but Major Whistler so convinced the President, Thomas B. Wales, of the folly of such a course, that the latter declared, with a most emphatic prefix, that he would have nothing to do with such a two-penny cowpath, and thus prevented its adoption.

Mr. Whistler had many investigations to make concerning the plans and policy of railroad companies at a time when almost everything connected with them was comparatively new and untried. When he commenced, there was no passenger railroad in the country, and but very few miles of quarry and mining track. If at that time an ascent of more than 1 in 200 was required, it was thought necessary to have inclined planes and stationary power. It was supposed that by frequent relays it would be possible to obtain for passenger cars a speed of eight or nine miles an hour. Almost nothing was known of the best form for rails, of the construction of the track or of the details for cars or engines. In all of these things Major Whistler's highly gifted and well balanced mind enabled him to judge wisely for his employers, and to practice for them the truest economy.

Major Whistler's employment upon the Western Railroad began while he was still engaged upon the Stonington line. In connection with his friend McNeill he acted as consulting engineer for the Western road from 1836 to 1840. From 1840 to 1842 he was its Chief Engineer, with his headquarters at Springfield. The steep grades west of the Connecticut presented not only a difficult problem in location and construction, but in locomotive engineering as well. At the present day we can order any equipment which may best meet the requirement upon any railroad, and the order will be promptly met by any one of our great manufactories ; but in the early days of the Western Railroad it was far otherwise, and the locomotive which should successfully and economically operate the hitherto unheard-of grade of over 80 feet to the mile was yet to be seen. The Messrs. Winans, of Baltimore, had built some nondescript machines, which had received the name of "crabs," and had tried to make them work upon the Western road ; but after many attempts they were given up as unfit for such service.

These "crabs" were eight-wheeled engines, weighing about 20 tons,

with a vertical boiler. The wheels were $3\frac{1}{2}$ feet in diameter, but the engine worked on to an intermediate shaft, which was connected with the driving axle in such a way as to get the effect of a five-foot wheel. These engines did not impress Major Whistler at all favorably ; and it is related that one Sunday the watchman in charge of the building in which some of them were kept, hearing some one among the engines, went in quietly, and overheard Major Whistler, apparently conversing with the "crab," and saying: "No, you miserable, top-heavy, lop-sided abortion of a grasshopper, you'll never do to haul the trains over this road." His experience in Lowell was here of great value to him, and he had become convinced that the engine of George Stephenson was in the main the coming machine, and needed but to be properly proportioned and of sufficient size to meet every demand.

With Major Whistler's work upon the Western Railroad his engineer ing service in this country concluded, and that by an occurrence which marked him as the foremost railroad engineer of his time. Patient, indefatigable, cautious, remarkable for exhaustless resource, admirable judgment and the highest engineering skill, he had begun with the beginning of the railroad system, and had risen to the chief control of one of the greatest works in the world, the Western Railroad of Massachusetts. Not only had he shown the most far-sighted wisdom in fixing the general features of this undertaking, but no man surpassed him, if, indeed, any one equaled him, in an exact and thorough knowledge of technical details. To combine the various elements in such a manner as to produce the greatest commercial success, and to make the railroad in the widest sense of the word a public improvement, never forgetting the amount of money at his disposal, was the problem he had undertaken to solve. He had proved himself a great master in his profession, and had shown how well fitted he was to grapple with every difficulty. He was equally a man of science and a man of business ; and to all this he added the most delicate sense of honor and the most spotless integrity. He was in the prime of manhood, and was prepared to enter upon the great work of his life.

It was not long after the introduction of the railroad that intelligent persons saw very plainly that the new mode of transportation was not to be confined to the working of an already established traffic, in densely populated regions, but that it would be of equal service in awakening the energies of undeveloped countries, in bringing the vast interior regions of the continents into communication with the seaboard, in opening markets to lands which before were beyond the reach of commerce ; and it was seen, too, that in event of war, a new and invaluable element had been introduced, viz., the power of transportation to an extent never before imagined.

Especially were these advantages foreseen in the vast empire of Russia, and an attempt was very early made to induce private capitalists to undertake the construction of the lines contemplated in that country. The Emperor, besides guaranteeing to the shareholders a minimum profit of four per cent., proposed to give them, gratuitously, all the lands of the State through which the lines should pass, and to place at their disposal, also gratuitously, the timber and raw materials necessary for

the way and works which might be found upon the ground. It was further proposed to permit the importation of rails and of the rolling-stock free of duty. Russian proprietors also came forward and not only agreed to grant such portions of their land as the railroads might pass through, gratuitously, but further to dispossess themselves temporarily of their serfs, and surrender them to the use of the companies, on the sole condition that they should be properly supported while thus employed.

With regard to the great line, however, which was to unite the two capitals, St. Petersburg and Moscow, it was decreed that this should be made exclusively at the expense of the State, in order to retain in the hands of the government and in the general interest of the people a line of communication so important to the industry and the internal commerce of the country. The local proprietors agreed to surrender to the government, gratuitously, the lands necessary for this line.

It was very early understood that the railroad problem in Russia was much more analogous to that in the United States than to that in England. The Emperor, therefore, in 1839, sent the Chevalier De Gerstner to the United States to obtain information concerning the railroads of this country. It was this person who obtained from the Emperor the concession for the short railway from St. Petersburg to Zarskoe Selo, which had been opened in 1837, and who had also made a careful reconnoissance in 1835 for a line from St. Petersburg to Moscow, and had very strongly urged its construction on the American plan. The more De Gerstner examined our roads, the more impressed he was with the fitness of what he termed the American system of building and operating railroads, to the needs of the Empire of Russia. In one of his letters, in explaining the causes of the cheap construction of American railroads, after noting the fact that labor as well as material is much dearer in America than in Europe, he refers to the use of steep grades (93 feet to the mile) and sharp curves (600 feet radius) upon which the American equipment works easily, to the use of labor-saving machinery, particularly to a steam excavating machine upon the railroad between Worcester and Springfield, and to the American system of wooden bridge building, and says: "The superstructure of the railroads in America is made conformable to the expected traffic, and costs therefore more or less accordingly;" and he concludes, "considering the whole, it appears that the cheapness of the American railroads has its foundation in the practical sense which predominates in their construction." Again, under the causes of the cheap management of the American roads, he notes the less expensive administration service, the low rate of speed, the use of the eight-wheeled cars and the four-wheeled truck under the engines, and concludes, "In my opinion it would be of great advantage for every railroad company in Europe to procure at least one such train" (as those used in America). "Those companies, however, whose works are yet under construction I can advise with the fullest conviction to procure all their locomotive engines and tenders from America, and to construct their cars after the American model."

Notwithstanding this report, the suggestions of De Gerstner were not at once accepted. The magnitude of the enterprise would not admit of

taking a false step. Further evidence was needed, and accordingly it was decided to send a committee of engineer officers to various countries in Europe, and to the United States, to select such a system for the road and its equipment as would be best adapted to Russia. These officers, Colonels Melnikoff and Krofft, not only reported in the most decided manner in favor of the American methods, but also stated that of all persons with whom they had communicated no one had given them such full and satisfactory information upon all points, or had so impressed them as possessing extraordinary ability, as Major George W. Whistler. This led to his receiving an invitation from the Emperor to go to Russia and become consulting engineer for the great road which was to connect the imperial city upon the Baltic with the ancient capital of the Czars.

When we consider the magnitude of the engineering works with which the older countries abound, we can but regard with a feeling of pride the fact that an American should have been selected for so high a trust, by a European government possessing every opportunity and means for securing the highest professional talent which the world could offer. Nor should it be forgotten that the selection of our countryman did not arise from any necessity which the Russian Government felt for obtaining professional aid from abroad, growing out of a lack of the requisite material at home. On the contrary, the engineers of the Russian service are perhaps the most accomplished body of men to be found in any country. Selected in their youth, irrespective of any artificial advantages of birth or position, but for having a genius for such work, and trained to a degree of excellence in all of the sciences unsurpassed in any country, they stand deservedly in the front rank. Such was the body of men with whom Major Whistler was called to co-operate, and whose professional duties, if not directed specially by him, were to be controlled by his judgment.

Accepting the position offered to him in so flattering a manner, he sailed for St. Petersburg about mid-summer in 1842, being accompanied on his voyage by Major Bouttattz, of the Russian Engineer Corps, who had been sent to this country by the Emperor as an escort. Arriving in St. Petersburg, and having learned the general character of the proposed work, he traveled, partly by horse and partly on foot, over the entire route, and made his preliminary report, which was at once accepted.

The plan contemplated the construction of a double track railroad 420 miles long, perfect in all its parts, and equipped to its utmost necessity. The estimates amounted to nearly forty millions of dollars, and the time for its construction was reckoned at seven years. The line selected for the road had no reference to intermediate points, and was the shortest attainable, due regard being paid to the cost of construction. It is nearly straight, and passes over so level a country as to encounter no obstacle requiring a grade exceeding 20 feet to the mile, and for most of the distance it is level. The right of way taken was 400 feet in width throughout the entire length. The roadbed was raised from six to ten feet above the ordinary level of the country and was 30 feet wide on top.

One of the most important questions to be settled at the outset in regard to this great work was the width of the gauge. At that time the

opinion in England as well as in the United States among engineers was setting very strongly in favor of a gauge wider than 4 feet 8½ inches, and the Russian engineers were decidedly in favor of such increased width. Major Whistler, however, in an elaborate report to the Count Kleinmichel argued very strongly in favor of the ordinary gauge. To this a commission of the most distinguished engineers in Russia replied, urging in the most forcible manner the adoption of a gauge of six feet. Major Whistler rejoined in a report which is one of the finest models of an engineering argument ever written, and in which we have perhaps the best view of the quality of his mind. In this document no point is omitted, each part of the question is handled with the most consummate skill, the bearing of the several parts upon the whole is shown in the clearest possible manner, and in a style which could only come from one who from his own knowledge was thoroughly familiar with all the details, not only of the railroad but of the locomotive as well.

In this report the history of the ordinary gauge is given, with the origin of the standard of 4 feet 8½ inches ; the questions of strength, stability and capacity of cars, of the dimensions, proportions and power of engines, the speed of trains, resistances to motion, weight and strength of rails, the cost of the roadway and the removal of snow are carefully considered ; the various claims of the advocates for a wider gauge are fairly and critically examined, and while the errors of his opponents are laid bare in the most unsparing manner, the whole is done in a spirit so entirely unprejudiced, and with so evident a desire for the simple truth as to carry conviction to any fair-minded person. The dry way, too, in which he suggests that conclusions based upon actual results from existing railways are of more value than deductions from supposed conditions upon imaginary roads, is exceedingly entertaining. The result was the adoption of the gauge recommended by him, namely, five feet. Those who remember the "Battle of the Gauges," and who know how much expense and trouble the wide gauge has since caused, will appreciate the stand taken thus early by Major Whistler ; and this was but one among many cases which might be mentioned to show how comprehensive and far-reaching was his mind.

The roadbed of the St. Petersburg & Moscow Railway was made 30 feet wide on top, for a double track of 5 feet gauge, with a gravel ballasting two feet deep. The bridges were of wood, of the Howe pattern, no spans being over 200 feet in length. The stations at each end, and the station and engine houses along the line, were on a plan uniform throughout, and of the most ample accommodation. Fuel and water stations were placed at suitable points, and engine houses were provided 50 miles apart, built of the most substantial masonry, circular in form, 180 feet in diameter, surmounted by a dome, and having stalls for 22 engines each. Repair shops were attached to every engine house, furnished with every tool or implement that the wants of the road could suggest.

The equipment of rolling stock and fixed machinery for the shops was furnished by the American firm of Winans, Harrison & Eastwick, who from previous acquaintance were known by Major Whistler to be skillful, energetic and reliable. Much diplomacy was needed to procure the large

money advances for this part of the work, the whole Winans contract amounting to nearly five millions of dollars: but the assurance of Major Whistler was a sufficient guarantee against disappointment or failure.

In 1843 the plans for the work were all complete, and in 1844 the various operations along the line were well under way, and proceeding according to the well-arranged programme. In 1845 the work had progressed so far that the construction of the rolling stock was commenced. The locomotives were of two classes, freight and passenger. The engines of each class were made throughout from the same patterns, so that any part of one engine would fit the same position on any other. The passenger engines had two pairs of driving wheels, coupled, 6 feet in diameter, and a four-wheeled truck similar to the modern American locomotive. The general dimensions were: Waist of boiler, 47 inches, 186 two-inch tubes $10\frac{1}{2}$ feet long; cylinders, 16×22 inches. The freight engines had the same capacity of boiler and the same number and length of tubes, three pairs of driving wheels, coupled, $4\frac{1}{2}$ feet in diameter, a truck and cylinders 18×22 inches, and all uniform throughout in workmanship and finish. The passenger cars were 56 feet long and $9\frac{1}{2}$ feet wide, the first class carrying 33 passengers, the second class 54 and the third class 80. They all had eight truck wheels under each, and elliptic steel springs. The freight cars were all 30 feet long and $9\frac{1}{2}$ feet wide, made in a uniform manner, with eight truck wheels under each. The Imperial saloon carriages were 80 feet long and $9\frac{1}{2}$ feet wide, having double trucks, or sixteen wheels under each. They were divided into five compartments and fitted with every convenience.

Early in 1847 the Emperor Nicholas visited the mechanical works at Alexandroffsky, where the rolling stock was being made by the Messrs. Winans, in the shops prepared by them and supplied by Russian labor. Everything here was on the grandest scale, and the work was conducted under the most perfect system. Upon this occasion the Emperor was so much gratified at what had already been accomplished that he conferred upon Major Whistler the decoration of the Order of St. Anne. He had previously been pressed to wear the Russian uniform, which he promptly declined to do; but there was no escape from the decoration without giving offence. He is said, however, to have generally contrived to hide it beneath his coat in such a manner that few ever saw it.

Technically, Major Whistler was Consulting Engineer, Colonel Melinkoff being constructing engineer for the northern half of the road, and Colonel Krofft for the southern half; but, as a matter of fact, by far the larger part of planning the construction in detail of both railway and equipment fell upon Major Whistler. There was also a permanent commission having general charge of the construction of the road, of which the President was General Destrem, one of the four French engineers whom Napoleon, at the request of the Emperor Alexander, sent to Russia for the service of that country.

The year 1848 was a very trying one to Major Whistler. He had already on several occasions overtasked his strength, and had been obliged to rest. This year the Asiatic cholera made its appearance. He sent his family abroad, but remained himself alone in his house. He would on no account at this time leave his post, nor omit his periodical inspections

along the line of the road, where the epidemic was raging. In November he had an attack of cholera, and while he recovered from it, he was left very weak. Still, he remained upon the work through the winter, though suffering much from a complication of diseases. As spring advanced he became much worse, and upon the 7th of April, 1849, he passed quietly away, the immediate cause of his death being a trouble with the heart.

Funeral services were held in the Anglican (Episcopal) Church in St. Petersburg. His body was soon afterwards carried to Boston and deposited beneath St. Paul's Church ; but the final interment took place at Stonington. The kindness and attention of the Emperor and of all with whom Major Whistler had been associated knew no bounds. Everything was done to comfort and aid his wife, and when she left St. Petersburg the Emperor sent her in his private barge to the mouth of the Baltic. "It was not only," says one who knew him well, "through his skill, ability and experience as an engineer that Major Whistler was particularly qualified for and eminently successful in the important task he performed so well in Russia. His military training and bearing, his polished manner, good humor, sense of honor, knowledge of a language (French) in which he could converse with officers of the government, his resolution in adhering to what he thought was right, and in meeting difficulties only to surmount them, with other admirable personal qualities, made him soon, and during his whole residence in Russia, much liked and trusted by all persons by whom he was known, from the Emperor down to the peasant. Such is the reputation he left behind him, and which is given to him in Russia to this day."

In 1849 the firm of Winans, Harrison & Eastwick had already furnished the road with 162 locomotives, 72 passenger and 2,580 freight cars. They had also arranged to instruct a suitable number of Russian mechanics to take charge of the machinery when completed. The road was finished its entire length in 1850, being opened for passenger and freight traffic on the 25th of September of that year, in two divisions, experimentally, and finally opened for through business on November 1, 1851. In all of its construction and equipment it was essentially American of the best kind, everything being made under a carefully devised system, by which the greatest economy in maintenance and in management should be possible. The use of standard patterns, uniformity in design and duplication of parts was applied not only to the rolling-stock, but to the railroad as well, wherever it was possible. Indeed, the whole undertaking in all its parts bore the impress of one master mind.

On the death of Major Whistler the government with jealous care prevented any changes whatever being made in his plans, including those which had not been carried out as well as those already in process of execution. An American engineer, Major T. S. Brown, was invited to Russia to succeed Major Whistler as Consulting Engineer. The services of the Messrs. Winans also were so satisfactory to the government that a new contract was afterwards made, upon the completion of the road, for the maintenance and the future construction of rolling stock.

While the great railroad was the principal work of Major Whistler in Russia, he was also consulted in regard to all the important engineering

works of the period. The fortifications at Cronstadt, the Naval Arsenal and docks at the same place, the plans for improving the Dovina at Archangel, the great iron roof of the Riding House at St. Petersburg, and the iron bridge over the Neva all received his attention. The government was accustomed to rely upon his judgment in all cases requiring the exercise of the highest combination of science and practical skill; and here, with a happy tact peculiarly his own, he secured the warm friendship of men whose professional acts he found himself called upon in the exercise of his high trust in many cases to condemn. The Russians are proverbially jealous of strangers, and no higher evidence of their appreciation of the sterling honesty of Major Whistler, and of his sound discriminating judgment could be afforded, than the fact that all his recommendations on the great questions of internal improvement, opposed as many of them were to the principles which had previously obtained, and which were sanctioned by usage, were yet carried out by the government to the smallest details.

While in Russia Major Whistler was sometimes placed in positions most trying to him. It is said that some of the corps of native engineers, many of whom were nobles, while compelled to look up to him officially, were inclined to look down upon him socially, and exercised their supposed privileges in this respect so as to annoy him exceedingly, for he had not known in his own country what it was to be the social inferior of any one. The Emperor, hearing of this annoyance, determined to stop it; so, taking advantage of a day when he knew the engineer corps would visit a celebrated gallery of art, he entered it while they were there, and without at first noticing any one else, looked around for Major Whistler, and seeing him, went directly toward him, took his arm and walked slowly with him entirely around the gallery. After this the conduct of the nobles was all that could be desired.

Major Whistler's salary while in Russia was $12,000 a year; a sum no more than necessary for living in a style befitting his position. He had abundant opportunity for making money, but this his nice sense of honor forbade. It is even stated that he would never allow any invention to be used on the road that could by any possibility be of any profit to himself or to any of his friends. He was continually besieged by American inventors, but in vain. The honor of the profession he regarded as a sacred trust. He served the Emperor with the fidelity that characterized all his actions. His unswerving devotion to his duty was fully appreciated, and it is said that no American in Russia except John Quincy Adams was ever held in so high estimation.

Major Whistler married for his first wife Mary, daughter of Dr. Foster Swift of the U. S. Army and Deborah, daughter of Capt. Thomas Delano, of Nantucket. By her he had three children: Deborah, his only daughter, who married Seymour Hayden, of London, a surgeon, but later and better known for his skill in etching; George William, who became an engineer and railway manager, and who went to Russia, and finally died at Brighton, in England, Dec. 24, 1869; Joseph Swift, born at New London, Aug. 12, 1825, and who died at Stonington, Jan. 1, 1840. His first wife died Dec. 9, 1827, at the early age of 23 years, and is buried in Greenwood Cemetery, in the shade of the monument erected to the

memory of her husband by the loving hands of his professional brethren. For his second wife he married Anna Matilda, daughter of Dr. Charles Donald McNeill, of Wilmington, N. C., and sister of his friend and associate, William Gibbs McNeill. By her he had five sons: James Abbot McNeill, the noted artist, and William Gibbs McNeill, a well-known physician, both now living in London; Kirk Boott, born in Stonington, July 16, 1838, and who died at Springfield, July 10, 1842; Charles Donald, born in Springfield, Aug. 27, 1841, and who died in Russia, Sept. 24, 1843; and John Bouttattz, who was born and who died at St. Petersburg, having lived but little more than a year. His second wife, who outlived him, returned to America, and remained here during the education of her children, after which she moved to England. She died Jan. 31, 1881, at the age of 76 years, and was buried at Hastings.

At a meeting held in the office of the Panama Railroad Company in New York, August 27, 1849, for the purpose of suggesting measures expressive of their respect for the memory of Major Whistler, Wm. H. Sidell being chairman, and A. W. Craven secretary, it was resolved that a monument in Greenwood Cemetery would be a suitable mode of expressing the feelings of the profession in this respect, and that an association be formed to collect funds and take all necessary steps to carry out the work. At this meeting Capt. William H. Swift was appointed president, Major T. S. Brown treasurer, and A. W. Craven secretary, and Messrs. Horatio Allen, W. C. Young, J W. Adams and A. W. Craven were appointed a committee to procure designs and estimates, and to select a suitable piece of ground. The design was made by Mr. Adams, and the ground was given by Mr. Kirkwood. The monument is a beautiful structure of red standstone, about 15 feet high, and stands in "Twilight Dell." Upon the several faces are the following inscriptions:

Upon the Front.

IN MEMORY OF
GEORGE WASHINGTON WHISTLER,
CIVIL ENGINEER,
BORN AT FORT WAYNE, INDIANA, MAY, 1800.
DIED AT ST. PETERSBURG, RUSSIA, APRIL, 1849.

Upon the Right Side.

EDUCATED AT THE U. S. MILITARY ACADEMY. HE RETIRED FROM THE ARMY IN 1833 AND BECAME ASSOCIATED WITH WILLIAM GIBBS M'NEILL. THEY WERE IN THEIR TIME ACKNOWLEDGED TO BE AT THE HEAD OF THEIR PROFESSION IN THIS COUNTRY.

Upon the Back.

HE WAS DISTINGUISHED FOR THEORETICAL AND PRACTICAL ABILITY, COUPLED WITH SOUND JUDGMENT AND GREAT INTEGRITY. IN 1842 HE WAS INVITED TO RUSSIA BY THE EMPEROR NICHOLAS, AND DIED THERE WHILE CONSTRUCTING THE ST. PETERSBURG & MOSCOW RAILROAD.

Upon the Left Side.

THIS CENOTAPH IS A MONUMENT OF THE ESTEEM AND AFFECTION OF HIS FRIENDS AND COMPANIONS.

While the monument thus raised to the memory of the great engineer stands in that most delightful of the cities of the dead, his worn-out body rests in the quaint old town of Stonington. It was here that his several children had been buried, and he had frequently expressed a desire that when he should die he might be placed by their side. A deputation of engineers who had been in their early years associated with him, attended the simple service which was held over his grave, and all felt as they turned away that they had bid farewell to such a man as the world has not often seen.

In person Major Whistler was of medium size and well made. His face showed the finest type of manly beauty, combined with a delicacy almost feminine. In private life he was greatly prized for his natural qualities of heart and mind, his regard for the feeling of others, and his unvarying kindness, especially towards his inferiors and his young assistants. His duties and his travels in this and in other countries brought him in contact with men of every rank, and it is safe to say that the more competent those who knew him were to judge the more highly was he valued by them. A close observer, with a keen sense of humor and unfailing tact, fond of personal anecodote and with a mind stored with recollections from association with every grade of society, he was a most engaging companion. The charm of his manner was not conventional, nor due to intercourse with refined society, but came from a sense of delicacy and a refinement of feeling which was innate, and which showed itself in him under all circumstances. He was in the widest and best sense of the word a gentleman; and he was a gentleman outwardly, because he was a gentleman at heart.

As an engineer, Whistler's works speak for him. He was eminently a practical man, remarkable for steadiness of judgment and for sound business sense. Whatever he did was so well done that he was naturally followed as a model by those who were seeking a high standard. Others may have excelled in extraordinary boldness, or in some remarkable specialty, but in all that rounds out the perfect engineer, whether natural characteristics, professional training, or the well-digested results of long and valuable experience, we look in vain for his superior, and those who knew him best will hesitate to acknowledge his equal.

THE VELOCITY OF LIGHT IN AIR AND REFRACTING MEDIA.

SYNOPSIS OF A LECTURE BY PROF. ALBERT A. MICHELSON, DELIVERED BEFORE THE CIVIL ENGINEERS' CLUB OF CLEVELAND, SEPT. 14, 1886.

Prof. Michelson, after a brief statement of some of the difficulties under which experimenters in this branch of science labored, gave a history of the measurements of light from the time of Galileo.* Before his time it was supposed that the perception of objects was instantaneous. As soon as the idea was promulgated that light proceeded from a body to the eye, the question arose, "How long does it take?" Galileo then began his experiments. The only absurdity was that it was supposed

* Taken chiefly from Prof. Newcombe's book.

that the velocity of light and sound might be of the same order of magnitude. Galileo suggested that two men should be stationed as great a distance apart as two lights should be visible. Each should have a lantern with a slide. As soon as the second experimenter saw the light uncovered by the first, he should uncover his lantern. The interval which elapsed from the uncovering of the first light till the observer perceived the light of the second, would be the time required for the light to come and go, plus the time required for the second observer to perceive the light and make the required movement. This experiment was tried by the Florentine Academy, and resulted in the conclusion that the time required was insensible. Yet upon this rude experiment was based the principle which underlies one of the most celebrated methods used in recent times for the attainment of the same object.

The subject was next approached from the astronomical side. In 1676 Roemer, in a communication to the French Academy, claimed that from his observations of the eclipses of the first satellite of Jupiter, he found that light required time to pass through the celestial spaces. He found 11 minutes to be the time required for light to pass over a distance equal to the radius of the earth's orbit. Dominique Cassini contested the right of Roemer's hypothesis to reception as an established theory, on the ground that the observed inequality might be a real one in the motion of the satellite itself. Other observations showed that the time assigned by Roemer for the "light equation" was somewhat too great. In 1809 it was fixed by Delambre at 493.2 seconds. In 1875 Glasenapp, then of Pulkowa, showed that results between 496 and 501 seconds could be obtained.

Bradley observed another peculiarity known as the aberration of fixed stars. He was attempting to find the parallax of a number of stars, and his observations led him to see that this was not the true parallax, but some other phenomenon. The theory of aberration is not quite satisfactory. The constant of aberration, however, gives a relation between the velocity of light and the velocity of the earth in its orbit, from which, by a simple calculation, the time required for light to pass from the sun to the earth may be deduced.

Professor Michelson then referred to the expense incurred by various nations in their observations of the transit of Venus. Astronomers now agree that the determination of the velocity of light gives a more accurate result than anything they can hope to gain from observations of the Venus transit. The distance of the earth from the sun is the astronomical base line, or astronomical unit. The distance from the sun was supposed to be 95,000,000 of miles, and as it required 500 seconds for light to traverse this distance, it was concluded that it moved 190,000 miles per second. Physicists were hopeless of measuring such a velocity by any means at their command, so no serious attempt was made between the time of the futile effort of the Florentine Academy and that of the researches of Wheatstone, Arago, Fizeau and Foucault nearly two centuries later.

In 1840 Fizeau presented a paper on this subject to the Academy of Sciences. His method was founded on the first experiment proposed by Galileo. A telescope was fixed upon a house at Suresne, pointing to the Hill Montmartre. A second telescope, looking directly into the first was

placed upon this hill, the distance between being about 8,633 metres. A small reflector was fixed in the focus of the second telescope. A transparent glass, fixed in the eye piece at an angle of 45 degrees, caused a beam of light to be sent from the first to the second telescope. This was directly reflected back, and, on its return, could be seen as a star by an eye looking through the first. A revolving wheel, with 720 teeth upon its circumference, was fixed upon the eye-piece of the latter so that the beam of light, both in going and coming had to pass between the teeth.

In 1838 Arrago proposed a method based upon that of the revolving mirror of Sir Charles Wheatstone. He took pains to demonstrate that it was possible, by the use of a revolving mirror, to decide between the theory of emission and that of undulations by determining the relative velocities in air and in a refracting medium. The difficulties, however, were such that he never succeeded in carrying out his experiments. Foucault and Fizeau, about the beginning of 1850, showed that the motion of light was slower through water than through air. There are two theories of light, the undulatory and the corpuscular, and this fact that light travels more slowly through water establishes the falsity of the corpuscular theory.

The next measures were those of Cornu. He adopted Fizeau's invention of the toothed wheel. His result was far superior in point of accuracy to that of Foucault who gave for the velocity of light 298,000 kilometers per second. Michelson, the next experimenter, gave a result of 299,910 kilometers per second. Messrs. James Young and George Forbes, experimenting in Scotland, promulgated a theory that there was a difference in the velocities of different colored rays, but it is probable that the phenomena observed by them arose from some other cause than a difference in the velocities of red and blue rays.

In Cornu's memoir upon the determination of the velocity of light, several objections are made to the plan followed by Foucault. The most important among these was that the deflection was too small to be measured with the required degree of accuracy. To employ this method, therefore, it was necessary that the deflection should be increased. In November, 1877, a modification of Foucault's arrangement suggested itself to Professor Michelson, by which this result could be accomplished.

The first experiment tried with the revolving mirror produced a deflection considerably greater than that obtained by Foucault. So far the only apparatus used was such as could be adapted from the apparatus in the Naval Academy. At the expense of $10 a revolving mirror was made which could execute 128 turns per second. This was installed at the laboratory in May, 1878. The distance used was 500 feet, and the deflection was about twenty times that obtained by Foucault. Various observations, with some changes in the apparatus, were made up to June 5, 1879, when the first of the final series of observations was made. Thirty sets made previous to this were rejected. After this time no set of observations, nor any single observation, was omitted.

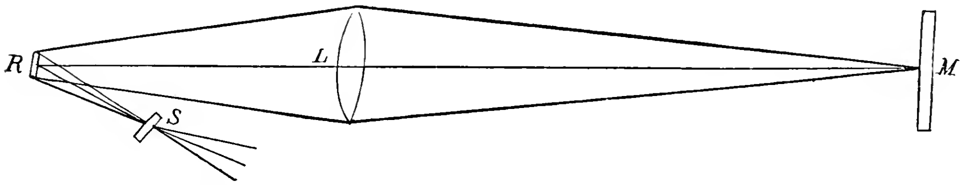
Professor Michelson then gave a blackboard illustration, showing the theory of the new method.

Let S be a slit, through which light passes, falling on R, a mirror free to rotate about an axis at right angles to the plane of the paper; L, a

lens of great focal length, upon which the light falls which is reflected from R. Let M be a plane mirror whose surface is perpendicular to the line $R\ M$, passing through the centres of R, L and M, respectively. If L be so placed that an image of S is formed on the surface of M, then, this image acting as the object, its image will be formed at S, and will coincide point for point with S. If now R be turned about the axis, so long as the light falls upon the lens, an image of the slit will still be formed on the surface of the mirror, though on a different part, and as long as the returning light falls on the lens an image of this image will be formed at S, notwithstanding the change of position of the first image at M. This result, namely, the production of a stationary image of an image in motion, is absolutely necessary in this method of experiment. It was first accomplished by Foucault, and in a manner differing apparently but little from the foregoing.

Suppose that R is in the principal focus of the lens L; then, if the plane mirror M have the same diameter as the lens, the first, or moving image, will remain upon M as long as the axis of the pencil of light remains on the lens, and this will be the case no matter what the distance may be.

When the rotation of the mirror R becomes sufficiently rapid, then the flashes of light which produce the second or stationary image become



blended, so that the image appears to be continuous. But now it no longer coincides with the slit, but is deflected in the direction of rotation, and through twice the angular distance described by the mirror, during the time required for light to travel twice the distance between the mirrors. This displacement is measured by the tangent of the arc it subtends. To make this as large as possible, the distance between the mirrors, the radius, and the speed of rotation should be made as great as possible.

The second condition conflicts with the first, for the radius is the difference between the focal length for parallel rays and that for rays at the distance of the fixed mirror. The greater the distance, therefore, the smaller will be the radius. There are two ways of solving the difficulty: First, by using a lens of great focal length; and, secondly, by placing the revolving mirror within the principal focus of the lens. Both means were employed. The focal length of the lens was 150 feet, and the mirror was placed about 15 feet within the principal focus. A limit is soon reached, however, for the quantity of light received diminishes very rapidly as the revolving mirror approaches the lens.

The revolving mirror consisted of a cast-iron frame resting on three leveling screws, one of which was connected by cords to the table, so that the mirror could be inclined forward or backward while making the observations.

A point of interest was the measurement of the speed of rotation. A

tuning fork, bearing on one prong a steel mirror, was used. This was kept in vibration by a current of electricity from five "gravity" cells. The fork was so placed that the light from the revolving mirror was reflected to a piece of plane glass, in front of the lens of the eye-piece of the micrometer, inclined at an angle of 45 degrees, and thence to the eye. When fork and revolving mirror are both at rest, an image of the revolving mirror is seen. When the fork vibrates, this image is drawn out into a band of light.

When the mirror commences to revolve, this band breaks up into a number of moving images of the mirror; and when, finally, the mirror makes as many turns as the fork makes vibrations, these images are reduced to one which is stationary. This is also the case when the number of turns is a submultiple. When it is a multiple or simple ratio, the only difference is that there are more images. Hence, to make the mirror execute a certain number of turns, it is simply necessary to pull the cord attached to the valve to the right or left till the images of the revolving mirror come to rest.

The electric fork had about 128 vibrations per second. No dependence was placed upon this rate, however, but at each set of observations it is compared with a standard Ut_3 fork, the temperature being noted at the same time. In making the comparison, the sound beats produced by the forks were counted for 60 seconds. It is interesting to note that the electric fork, as long as it remained untouched and at the same temperature, did not change its rate more than one or two hundredths vibrations per second.

Professor Michelson then gave a description of some of the mechanical appliances used in making his experiments. With regard to the revolving mirror, two binding screws, terminating in hardened steel conical sockets, held the revolving part. This consisted of a steel axle, the pivot being conical and hardened. The axle expanded into a ring which held the mirror. This was about one and a quarter inches in diameter and two-tenths of an inch thick. It was silvered on one side only, the reflection taking place from the outer or front surface. A species of turbine wheel was held on the axle by friction. This wheel had six openings for the escape of air. The air entering on one side acquires a rotary motion and carries the wheel with it.

Other mechanical appliances were explained by blackboard diagrams.

In answer to the question: "Were your results at Annapolis different from those obtained here?" Professor Michelson stated that the results at Annapolis gave for the velocity of light 186,360 miles per second, while the result in Cleveland was 186,325.

Mr. Eiseman: What were Professor Newcomb's results?

Professor Michelson: Professor Newcomb made a number of experiments, using the same method as Foucault's. When he finished his first series of experiments he found that his result was 200 miles less than mine. He tried to discover the error first in his own work and then in mine. He asked me to repeat my experiments, which I did. His best result is now given as 186,330 miles per second.

A Member: How did these results compare with the best results obtained by observation of Jupiter's satellites?

Prof. Michelson : I think the result obtained by Fizeau coincided remarkably with the result obtained from observations of the eclipses of Jupiter's satellites. That was 190,000 per second.

Fizeau	190,000 miles per second.		
Foucault	185,000	"	1862
Cornu	186,660	"	1874
Michelson	186,360	"	1879
"	186,325	"	1882
Newcomb	186,330	"	1882
Young and Forbes	187,250	"	1881

As it had been announced that Messrs. Forbes and Young had detected a difference of two per cent. in the rates of transmission of red and blue light. Professor Newcomb, in his experiments at Fort Myer, watched carefully for traces of color in the reflected image, but nothing could be discovered.

PROPOSED PLAN OF TRUSS BRIDGE FOR VERY LONG SPANS.

By J. Freeman Clarke, Member of the Western Society of Engineers.

[Read April 6, 1886.]

To increase the spans of bridges to lengths greater than can be made by present plans can be accomplished only by such a combination of systems as will reduce the load borne by each, unless some entirely new type be invented. And as the types of the present single plans are the arch, the wire suspension and the truss, a span greater than can be reached by either of these must be had by such combination of one or more of those systems as will compel each part to bear its proper proportion of the load, at all times and under all circumstances. The combination now proposed secures entire independence, yet complete harmony of action of the parts, the lack of which in combinations heretofore employed has rendered them objectionable.

If an endless wire rope be made to move freely over pulleys fixed near the top of two towers placed apart from each other, and the endless rope be then connected in the middle, it will sustain twice the weight that the same rope will when not connected in the middle—a fact readily shown by the most simple experiment.

Let there be now introduced an arch abutting at the foot of each tower, the outer thrust being held by the weight of the towers, or by a chain of bars held together by bolts, passing through eyes in the chord bolts (as usual in bottom chords of ordinary trusses). Then by use of wire rope suspenders passing from the arch around pulleys fitted to the bolts in the chain of bars, thence to either the upper or lower portion of the endless wire rope (which forms in fact an upper and a lower cable), while another suspender is let down from the other portion of the endless cables to the chord bolts to each panel, it is evident from the equality of action and reaction, the arch and each cable (or upper and lower portion of the endless wire rope) necessarily bear the same proportion of the load and weight taken by the suspenders, and the load taken by each is at once transmitted through it to the ends, and each must at all times bear its equal portion of the load, so long as the suspenders and cables are free to adjust themselves to each other.

Such are the novel features of the plan, being the use of an upper and lower cable (or sets of cables) reacting on each other and through wire rope suspenders on an arch (or another cable or a truss), with which they are thus made to combine and divide the load.

The result is the combination of the lightness, elasticity and durability of the wire suspension bridge, with the stiffness of the arch or truss, forming a bridge capable of far greater length of span than can be had by either system separately.

Among the advantages secured then are :

First. Entire independence but complete harmony of action between the parts; whence the investigation of either one of the systems is to be made separately and independently of the others, each calculated to bear its own weight and ⅓ of the load. And to secure this independence and harmony, it is not necessary that there be any actual motion of the cables, or suspenders, but only a certain elasticity or reciprocity of action between the systems, the structure being built with ordinary care and accuracy; whence the use of pulleys at the ends (which have been introduced in order to illustrate the principle, but which, in case of very large cables, would be almost impracticable), is not at all necessary, but any device will answer, that secures reciprocity of action, however slight, between the systems.

Second. Great length of span. For since each system bears only one-third of the load, each can be extended to greater lengths than when it takes the whole load. The usual calculations give the limit of span of the cables to be 4,500 feet, when each bears only one-third of the load. Here, however, the length is limited to somewhat less than this, first by the arch itself, and second by the limit in deflection that can be allowed the cables. By abutting the arch against the foot of the piers and extending its height to that of the towers, the length of the arch bearing one-third of the load can be made very great, and again the arch may be discarded and in its stead a cable used (exactly as in ordinary iron suspension bridges) to which the suspenders are attached, instead of the arch as described above. Except as to matters of stiffness, this arrangement might be preferred to the use of the arch.

Third. Great stiffness in any length of span, for (the arch being used) may be braced and stiffened somewhat, as in the bow-string bridge, and may be further trussed to top girders, which, in case of single spans, may be placed between the tops of the towers, to take the horizontal strain of the cables. And again, as each system reacts upon the others through the wire rope suspenders, the tendency of either cable to rise produces only a pressure on the ends of the struts.

A fourth advantage is the use of just such material and tools as are ordinarily employed in bridging, requiring no extra lengths, and, therefore, no special plant. And the longer pieces used in the construction perform no important office, but only that of counterbracing or struts.

Hence follows a fifth advantage, economy in construction, arising from the selection for combination of the most economical plans for taking the load and transmitting them at once to the ends.

We would call attention to the light and graceful appearance of the structure, and especially to the advantage in regard to material in

important members and parts, being less bulky and therefore less liable to hidden defects, besides a certain slight elasticity in the whole, so conducive to strength and durability in case of sudden impact or shock, as in heavy travel or railroad traffic.

The advantage of dividing the load, *in order to secure increased length of span*, can be shown by this simple illustration: Suppose we had two single wires of equal deflection and fastened at ends. the first loaded to its utmost capacity, the second bearing its own weight only; it is evident the latter will be under much less tension than the first; and, therefore, the same angle of deflection being preserved, the latter can be extended to much greater length—to a length limited by the tension from its own weight becoming equal to the tension produced in the first wire from load and weight at shorter length.

Description of the accompanying figures.

Fig. 1 represents a span of 1,000 ft. in which one set of double reacting cables is used in connection with the arch. In this case a bridge of great stiffness is had by the use of adjustable struts, *d*, *e*, *f*, *g*, etc., in connection with the suspension ropes as ties, for in addition to the smaller proportion of the load to the weight, it must be remembered that any tendency of one of the cables to rise, pulls with equal force on the arch, causing only a pressure on the ends of the struts. The claim of economy is illustrated in a comparison of long spans of this design with spans of same length of the other trusses, or cantilever bridge.

Fig. 2 shows a design for securing such elasticity or reciprocity of action between two cables in either truss that they will react upon each other. The two cables, which pass over the towers alongside of each other, are held apart a short distance from the top of the tower by an iron sector *a b c*, the cables being firmly held together at the pivotal point *c*. *a c* and *b c* being radii of a circle, the portion of the cables between *a c* and *b c* will remain the same, but any excess of tension of one cable over the other will evidently be at once equalized by the points *a* and *b* moving to such position as to lessen the sag of one cable and increases the sag of the other cable. thus securing complete harmony of action between the cables, though if the structure is executed with ordinary care and accuracy, there need be no actual movement of the points *a* and *b*.

Fig. 3 represents the general arrangement of the suspenders in cases where the double cable are used with the arch. The suspender attached to the arch may be made to pass over a small pulley (movable about a bolt in the bottom girder at each panel) and thence carried to one of the cables to which it is attached, as usual in wire suspension bridges; or instead of the pulley a small sector may be used, to the radii of which the wire rope suspenders are respectively attached, while a third suspender from the other cable is attached to the bolt about which the pulley or sector is movable. The cables may sag on either side of the arch.

When the weight of the cables exceeds that of the load, sufficient stiffness is had by a truss in connection with the track.

Fig. 4 shows the general plan of a span 3,000 feet long, in which two sets of double cables reacting on each other are used.

Fig. 5 shows the general arrangement of the suspenders and truss.

Four suspenders are let down from the cables and attached to two sectors at each panel (or small pulleys instead may be used). By the use of the two sets of cables as in Fig. 4, the limit of span is increased to twice that of the single cable, or to 5,000 feet, when the cable is deflected to $\frac{1}{8}$th of span, for in this case the weight of each cable is to weight of load and cable as 1 is to 1.5, when (in the same case) it is as 1 to 3 in the single cable.

The object of this paper is to draw out criticisms and suggestions, in regard to the merits and demerits of this particular plan for exceedingly long spans, from those experienced in this line of work, and the writer trusts it may lead to such an interchange of views as will prove advantageous to those interested in this extremely interesting branch of engineering.

LETTERS DISCUSSING MR. CLARKE'S PAPER.

By Mr. A. Gottlieb.

I have read the paper and examined the sketches treating the subject, "Proposed Plan of Truss Bridges for Very Long Spans." The general idea of the subject has frequently been brought forward, and formerly also embodied in practice, but wisely abandoned. Who has not seen old Howe truss bridges combined with an arch abutting against the masonry? The details proposed in the paper and the forms used are indefinite and not clear, and I shall not enter into any detailed criticism of the same. I shall confine myself merely to stating my views about the principle involved.

The objects aimed at in any construction are durability and safety, combined with the utmost permissible economy. The question now is, Can these objects be better attained in construction of bridges (no matter whether of long or short spans) by combining two different systems, than by a single system? I say, decidedly, No! My reasons are as follows:

First, as to their durability and safety.

It is impossible to determine by any arbitrary assumption how much of the load or weight on the bridge should be supported by one, and how much by the other system. It is impossible, even if the same material is used in the construction of both, to have the dead weights of the structure so equalized, and the mechanical workmanship so perfect, as to have any reasonable assurance that the allotted share of these weights, and nothing more, be carried by the one or other system.

The various applications of the live and moving load, the deterioration of material, still more aggravate the case. If different materials, however, are used, like iron in one and wood in the other, or wire ropes in one and stiff rolled bars and plates in the other, the difference in expansions and contractions under loads, or in varying temperature, are so great as to frustrate any accurate calculations. The only safe way would be to construct both systems so as to carry the whole load, which would, of course, render one of the systems entirely useless.

In the old Howe truss bridges above referred to, it was found that their unequal straining of the arch and trusses was a detriment to both, rendering, in fact, both weaker than they would have been by themselves. The arches have therefore been abandoned, and the expense for-

Fig. 1.

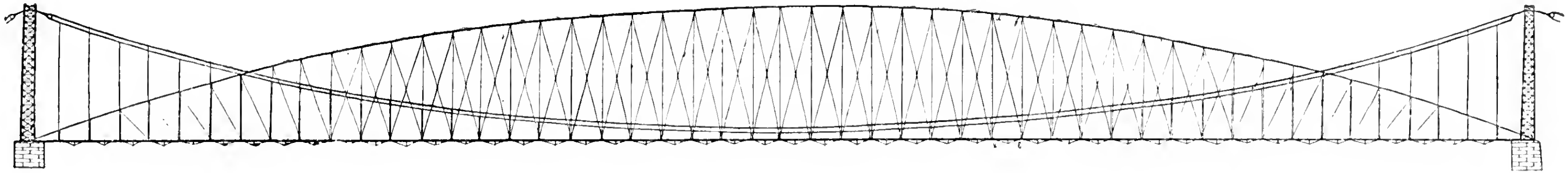


Fig. 2.

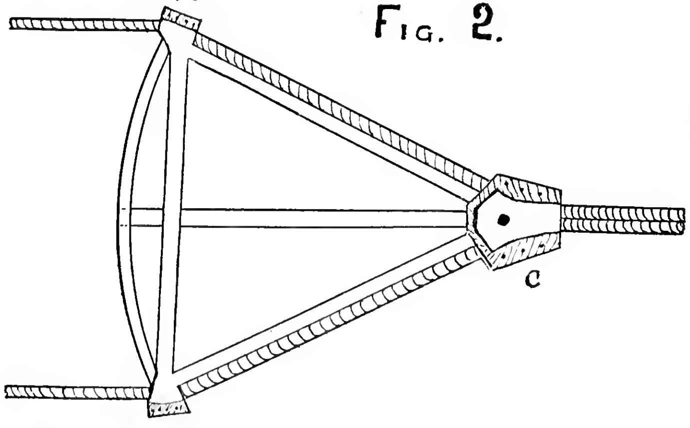


Fig. 3.

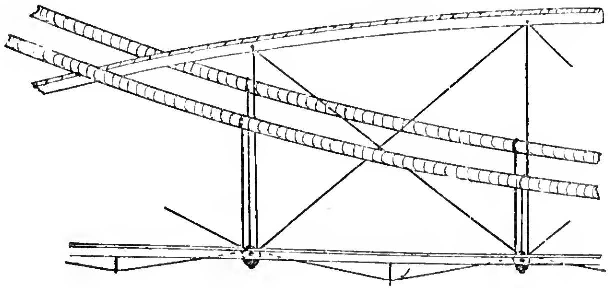
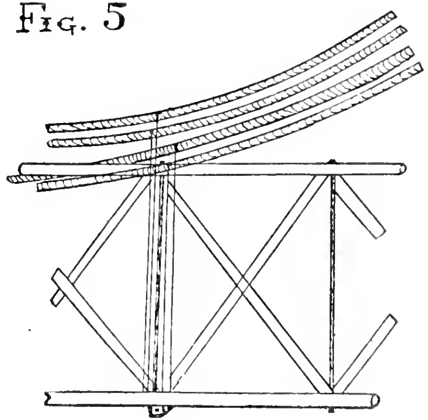


Fig. 5



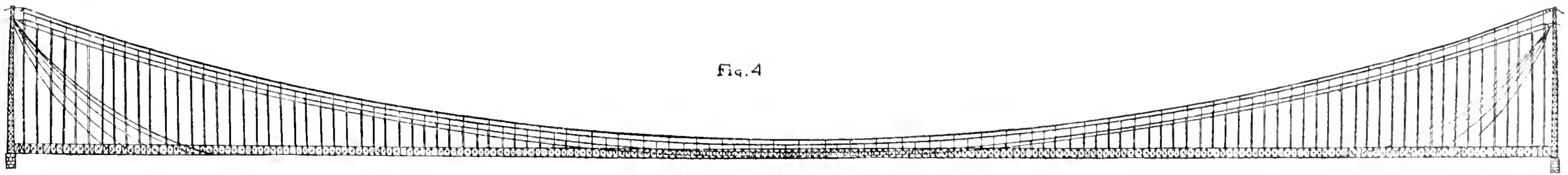


Fig. 4

merly incurred in providing arches and heavy masonry turned towards strengthening the trusses themselves, and with good result.

Second, as to economy.

Now supposing as granted, for argument's sake, that it would be possible to overcome, in some way, the objections stated in the first part, where should the saving come from?

If for a certain span a certain amount of material, and consequently dead weight of bridge, is needed to support a certain amount of live or moving load, what difference does it make whether you put that material into one truss, one arch, one suspension bridge, or whether you put it into a combination of two or three such structures. On the contrary, it is an absolute waste of material as well as labor, as well in the shops as in erection.

In former times, when the facilities for rolling and handling heavy pieces were not as perfect as they are to-day, long iron bridges were constructed with twin trusses, that is, two trusses used on each side of roadway instead of one coupled together. The channel span of the Ohio River, for instance, between Cincinnati and Newport, is constructed in that way. But it is evident that were that bridge constructed of single trusses only, for every two pieces manufactured in the shops or handled in erections only one would have been made and so much expense saved.

Besides, in every structure there are certain parts, in connections as well as truss members, which cannot be made as light as the theoretical calculations would permit them to be, consequently material must be wasted. In one system it is wasted once, in two, of course, twice. Modern structures are, therefore, made with single trusses or arches, and combinations of systems are avoided.

April, 1886.

By Mr. Maurice Seifert.

Having read the paper of Mr. Clarke on very long span bridges and overlooked the strain sheets and plans attached to same, also perused Mr. A. Gottlieb's criticism concerning this paper, I am inclined to say that I fully concur with Mr. Gottlieb's view of the matter.

I do not think that this plan of construction of a bridge, if accepted and executed, would prove a practical success, as I do not believe that the two systems would work harmoniously together, as the author claims. Nor do I think this manner of construction to be more economical than any other system of long span bridges at present in use.

June, 1886.

By Mr. G. R. Bramhall.

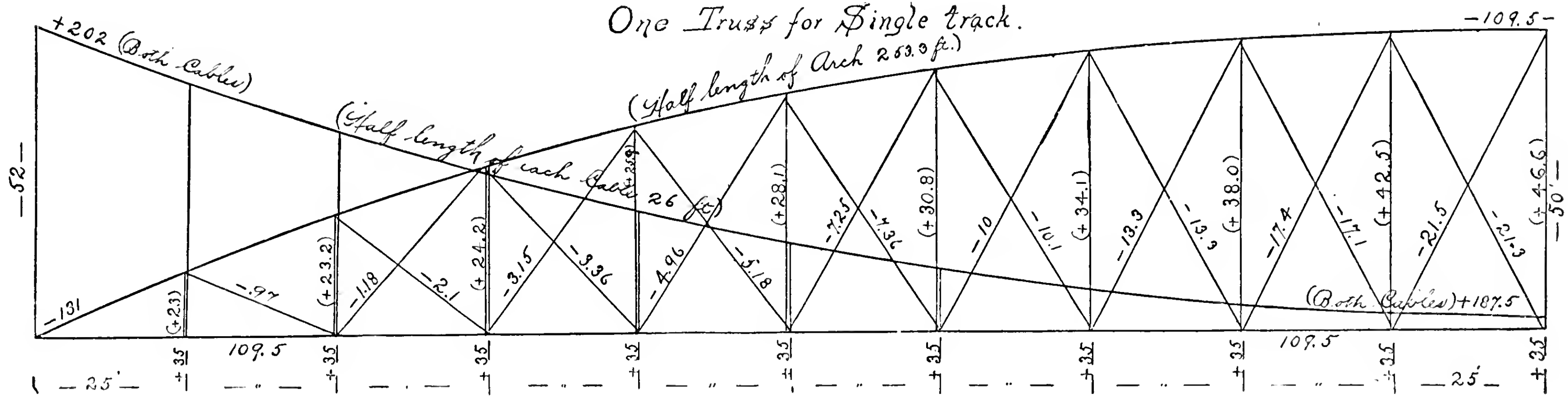
I have examined the sketch and paper submitted by Mr. James Freeman Clarke, for his combination truss and suspension bridge.

While there is no doubt a bridge of this class may be built, I am unable to see or understand the utility or economy of such a structure.

Besides, it appears quite plain to my mind that it will be exceedingly difficult, if not impossible, to secure the harmony or reciprocity claimed by combining two principles so directly opposite in bridge building: the suspension and the truss and arch.

Strain Sheet for 500 ft. Span. Panels 25 ft. each.

One Truss for Single track.



Scale, 37.4 ft. = 1 inch.

The strains are given in tons of 2,000 lbs. The live load is taken at 1 ton per lineal foot of entire length of bridge ; the greatest load at any point at 2 tons per lineal foot.

The live and dead weight combined borne by each double cable (which together bear one-third of entire load and weight) is taken at .60 of ton per lineal foot of span ; and that of each arch (which bears half the weight of the top lateral bracing in addition to what each cable bears) is taken at .375 of ton per lineal foot.

The greatest strain on the suspenders at each panel = 25′ (1 panel length) × 2.80 (greatest load in tons, live and dead weight) = 70 tons, which will give for the 3 suspenders of each panel in one truss = 35 tons. As the suspender attached to the arch acts also as a tie to its share of load and weight, 11.6 tons must be added.

Note.—The above calculations for strain sheet are made with 1 *ton as an unit*, and therefore are the same whatever the ton is taken at, and will answer for ton of 2,240 as well as 2,000 lbs.

One or the other of the principles or systems would necessarily have to carry the burden.

In a word, I fully concur in Mr. Gottlieb's views.

REPLY TO MR. A. GOTTLIEB'S CRITICISMS.

By Mr. Clarke.

In a paper suggesting so new, and, it may be said so bold, an idea as a plan for building spans of bridges of more than double the length of the longest yet undertaken, definiteness and clearness in the minuter details might well be regarded as a matter of secondary importance.

Mr. Gottlieb's adverse criticism is, perhaps, largely due to a lack of a full recognition of this fact—that the object proposed to be obtained by the new plan is *not* a better nor a more economical bridge than structures now in use, but a practical plan for *longer spans than can be had by any other.*

This being the object in view, no criticism which loses sight of this can be just or of any value as a guide to the merits of the plan under discussion, and if it be admitted that other plans are more economical and preferable in *short* spans, yet the claims are still intact, that the strains are here taken up and transferred to the ends in the most economical manner, and that longer spans can be had by this than by any other plan. But in stating his views about the principles involved, it seems to me Mr. Gottlieb must either have failed to understand the plan, or feared a weakness in his argument, and therefore endeavored to create in advance a prejudice against the proposed plan, by comparing it with that at one time adopted, of strengthening a Howe truss bridge with an arch.

In the latter case, it is evident the one can only take a share of the strain, as the other fails to do so.

Here, however, it is equally evident upon examination, that a new and different arrangement of the suspenders must be made to compel one part of the system to bear more of the load than the others ; that with the usual care in the workmanship, it is as necessary for each part to bear an equal share of the load as it is that action and re-action must be equal.

And, indeed, the arch or truss is incidental and not necessary in the proposed combination, since the longest spans are obtained by combining the wire suspension cable with itself in such manner as to secure certain and harmonious co-operation.

This being true, Mr. Gottlieb's objection that it would be impossible to determine the exact strength needed for each part necessarily falls to pieces. Each system being compelled to bear its own weight and an equal share of the load (if either bears any at all), the calculation for each must be the same as for any single structure of the same plan.

Any structure, especially any long span bridge, is liable to the objection urged for unequal expansion and contraction ; but surely the proposed plan is *least liable* of all others to this objection, since the elongation or contraction of any of its main members can cause only a re-adjustment of the suspenders and cables to each other, for which the plan is especially provided; indeed its adaptability to changes of tempera-

ture specially recommends it in cases of very long spans, and upon its use *for very long* spans its other claims rest.

For to explain, if we have two single wires suspended at equal angles of deflection, the one loaded to its utmost capacity, the other with, say, only one-half of this load, it is evident that, while the former cannot be extended at all without breaking, the latter can be lengthened the same deflection, and, therefore, the same co-efficient of tension being preserved till the accumulated weight from increased length of wire equals the tension in the first instance. What is true of one wire is of course true of several put together, as in a cable. Therefore the division of the load and lessening the weight on each cable allows of an extension of the span beyond what can be had where the load is all taken by one cable.

The dividing of the load between two or more instead of one system, is not therefore primarily, as Mr. Gottlieb seems to infer, the object in view; but a means by which longer spans can be had, and of rendering practical very long spans by allowing the use of material lighter and more easily handled, in which defects are less liable to occur and more easily detected when they do occur.

The argument, therefore, of a saving in expense in manufacturing fewer pieces, while entirely true in comparatively short spans, is reversed here, where reduction in the size of each piece is important, since "*all* the parts *can* be made as light as the theoretical calculations would permit them to be."

We must conclude, therefore, and think that the unprejudiced engineer who takes the pains to investigate the matter will agree with us, that Mr. Gottlieb has failed fully to appreciate the purpose and aim of the proposed plan, and therefore that his criticisms are not the result of a thorough, careful and impartial investigation of the subject.

DRAINAGE AND PLUMBING IN DWELLINGS.

By Theodore Rosenberg, Member of the Civil Engineers' Club of Cleveland.

[Read August 10, 1886.]

The special literature on the subject on hand would fill a good sized professional library, and it is not the purpose of this paper to treat the matter of drainage in more than the merest outlines, while the subject of sanitary plumbing applied to dwellings, having come more under my special notice and observation, will receive more consideration. It has long been a matter of astonishment to me how a host of intelligent house owners are liable to err so glaringly in the choice of their plumbing apparatus, and remain so utterly oblivious to the necessity of an efficient drainage. We still see the best cabinet finish around washbowls, water-closets and bath tubs, all of which are fitted with silverplated nozzles, chainstays and other highly elegant appurtenances, but which are at the same time very improperly trapped, insufficiently vented, and their soil connection is anything but satisfactory. The above finish serving only to conceal

deficiencies, to prevent aeration around the fixtures and to facilitate the accumulation of filth, and the generation of a close smell, it has, for some reason, become the custom in certain quarters to term such finish, as "modern improvements," and a house containing the greatest amount of plumbing, or rather the concealment of the real plumbing apparatus, is frequently called a "modern house." This might sound a little preposterous, but it may be taken for granted and could be proved by numerous instances that the above statement is not a mere casual one, but that it is based on actual observation.

The root of all the evil seems to lay in the general state of our health ordinances and the lack of system in the arrangement of our city sewers. It is not every householder's fancy to ventilate the public sewer through the soil-pipe in his own dwelling, and being probably ignorant of the existence of the appliance called fresh air inlet, which, by the way, is not too eagerly recommended by the average plumber, he disposes of his house waste in the patriarchal style of his forefathers ; that is, he is satisfied to construct a cesspool or even the most pernicious of all the second and third rate sewage receptacles, the privy vault. Notwithstanding the imperfect system of our city sewers, it is possible to so effectually ventilate the soil pipe of a dwelling, that there seems to be really no excuse for the omission of ventilated sewer connections.

The drainage of a dwelling goes hand in hand with the building of the foundation, in fact the former should receive the greatest possible attention, not only on account of the safety of the latter, but also because of the danger to the health of the inmates arising from faulty construction. But, alas ! right here is the first disappointment in store for the ambitious young architect. He has designed the plans after due consultation, his estimates agree fairly with the bids ; the elevations are pleasing to the eye, the general appearance of the building promises to be advantageous, the interior finish has received the approval of the lady of the mansion, even the number of closets was quite up to her expectations, but the architect's demand for an extra credit wherewith to provide for a concrete foundation under the wall and a French drain, and filling in with broken stone around the same, which extra has turned up at the last moment, that is, as soon as the excavation developed a dangerous subsoil, meets a deaf ear. He is satisfied that he has done his duty, calls the attention of the house-owner to the future unpleasant circumstances likely to occur if his demand is not granted and, finding his warnings unheeded, proceeds with the work. The building might now, or might not, be under roof before the first heavy showers set in; at any rate it is quite certain that there will be a damp foundation to that dwelling, resulting in a damp cellar, with moldy wall-faces, dripping after every shower or whenever the ground-water rises above the level of the cellar floor, and after the furnace has been working for some time there will be a peculiar smell in the rooms above the cellar not unlike that of a newly plowed field, and the spring is likely to announce its appearance by a gentle peel ing off of plastering, caused by the ascending moisture, which pervades the spaces between the studdings ; in short, after a year or two of habitation every one of the warnings of the architect have proved to

be well founded, and all manner of means are resorted to to remedy the evil; but, in most cases, this is a hopeless task. Now, what should have been done in the first place, provided the subsoil was not perfectly dry, was to deepen the trenches some 12 or 18 inches below the under side of the footings, and also extend such deepening sideways all around the walls about one foot wide, to fill the whole subtrench with dry spalls or coarse gravel, to grade the same toward one or two points from which one or more drains, filled like the subtrench, ought to have been run toward an auxiliary dry well of proper capacity to receive the subsoil drainage and carry it safely away from beneath and around the house. It would have been only proper to cover the outside face of the wall with cement mortar and finish up with a layer of hot asphaltum of tar up to the grade line, where a damp proof course of slate should have been laid in pure cement between the wall courses. It is needless to add that the cellar floor should have received the same treatment, but it might be assumed that there was an appropriation granted for such purposes. Of course there are different ways by which to attain the same result. There might have been a line of drain tiles used, with or without a solid layer of concrete under the footings, or in some cases low arches in rubble might have been necessary, but such construction as first outlined will suffice in the majority of cases. None of the methods indicated having been employed, however, in the case in hand the results hinted at above are sure to follow, and no amount of paneling, wainscotting or Moorish fretwork, not even the innocent device of a gilded wood shovel below two Japanese fans above the hall mantel, or a Chinese parasol at the parlor frieze will effectually assist in converting that ill-fated house into a healthy home. All this and a vast deal more has been said, read and written by our foremost sanitary engineers, with more or less visible results, principally less, the further west we go, and the denser the population grows in and around manufacturing cities.

My suggestions, however, refer more particularly to local matters. It will probably be a suprise to you to hear that drainage and sewerage are conceived to mean the same thing, still I have often heard people express their astonishment at their being blessed with a damp cellar—which they did not specify in particular, but got it nevertheless—while they had paid the plumber so much and had all "modern improvements" in their houses. To many people it is likewise a conundrum how the architect should be able to know so much of the business of his neighbor, the plumber, whose sign teaches you that he is not merely a book-learned, but, on the contrary, a practical plumber, who has served his time, sir, and is employed just now at putting in a business block, steam-fitting, gas-piping fixtures, and all the plumbing, worth in all several thousand dollars—proof enough of his practical and theoretical knowledge.

It would tax your patience beyond the purpose of this paper were I to cite the many instances in which I have observed the most glaring mistakes and wanton neglect perpetrated by members of that often slandered craft whose very name creates a feeling of yearning in the heart of many a good housewife for the end of all things domestic and sanitary. Still we must have plumbing apparatus, properly applied,

judiciously selected, and, first of all, its construction should be watched most assiduously. The time spent upon that task will be amply repaid. And it may be stated right here that the money intelligently expended upon the plumbing apparatus will bear interest at an incalculable rate. There must be a limit to all things and the sooner the prospective house dweller limits the expenditure or the different items likely to make up his house the better he will be off. If he consults an architect he might in the majority of cases facilitate matters. But the course of true building never did run smooth and the fact that the neighbor's porch is just the thing that is wanted and the other neighbor's Queen Mary Ann Eliza's front gable is compulsory, while there are over town two dormers on some crazy quilt roof that are just too lovely for anything, works so much to alter original plans, arrangements and estimates, that the architect, who had, so to speak, been on a high horse and had specified the very best plumbing in the market, all connections perfect, in the very best and strongest manner, and so forth, with grace, contents himself finally to modestly remark something about a four-inch cast iron soil-pipe, is satisfied with galvanized steel sinks in place of the celebrated earthenware patterns, and otherwise is very much disheartened, except when he concludes that the whole plumbing system is subject to rigid inspection by the health board, and will be accepted only after satisfactory peppermint test, etc. Result: The house is a very fair-looking one, with a very frail soil stack fastened by thin strips of iron to the frame-work, and the fixtures are in turn supported by the floors. The frame-work shrinks most intricately, the fastenings designed to connect floor and fixtures change their places in some mysterious manner, connections show appalling fissures, and everybody is in despair except the plumber, whose bill for repairs by this time commences to assume the proportion of that for the new work. Some years go by, and the bills return with never-failing regularity. This is not wholly the plumber's fault, although from the way in which the craft has been criticised by men of undoubted professional standing, it would appear that the greater part of the blame may be laid to the plumber. I have had very bad and very good results with plumbers—according to the time I was able to employ in the supervision of their work. I had the best results where I could purchase the material and have the work done by the day. By *best results* I mean that the work was done for an amount below the lowest bid for labor and material, and better in regard to workmanship. But, as the supervision costs money, the work was done at an expense to the owner certainly not less than the lowest bid—but, then, the work was better in every respect.

The foregoing remarks would seem to indicate that good plumbing work cannot be had except under the personal supervision of the architect. This is true if applied to individuals. Candor compels me to state that there are a number of conscientious plumbers to select from in this city and elsewhere, and the architect, if left to himself, is generally able to select a good plumber, as he certainly will in the interest of his own professional standing. The architect who is bound to have perfect soil connections, such as are not apt to leak and will be rigid and gas tight when in common use in dwellings, will have to specify heavy or double

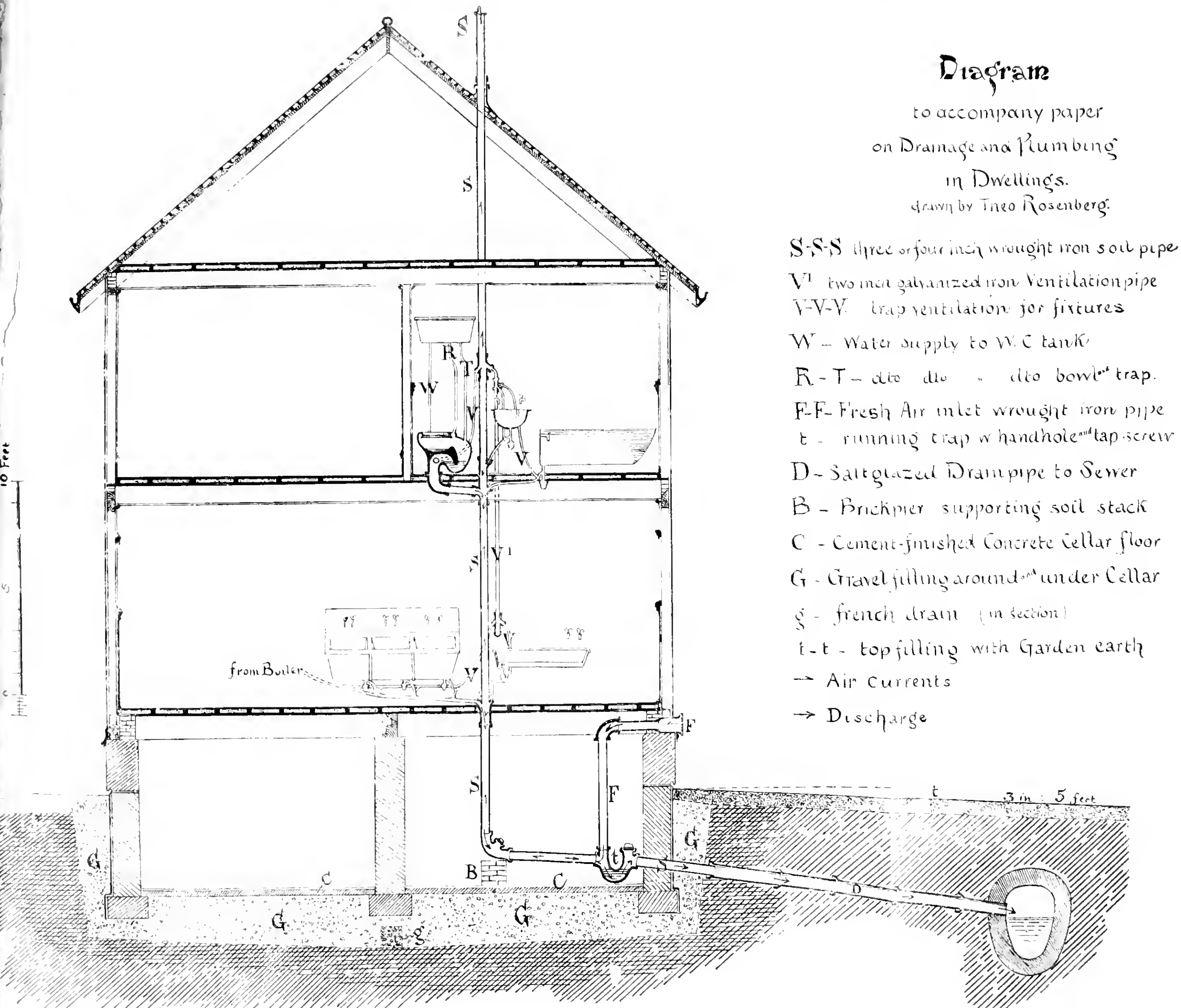


Diagram
to accompany paper
on Drainage and Plumbing
in Dwellings.
drawn by Theo Rosenberg.
S-S-S three or four inch wrought iron soil pipe
V1 two inch galvanized iron Ventilation pipe
V-V-V trap ventilation for fixtures
W – Water supply to W. C tank
R-T – dto dto – dto bowl and trap.
F-F- Fresh Air inlet wrought iron pipe
t – running trap w handhole and tap screw
D – Saltglazed Drainpipe to Sewer
B – Brickpier supporting soil stack
C – Cement-finished Concrete Cellar floor
G – Gravel filling around and under Cellar
g – french drain (in section)
t-t – top filling with Garden earth
→ Air Currents
→ Discharge
from Boiler
10 Feet
3 in : 5 feet

thick cast or wrought iron pipe, carefully tested as to equal thickness, enameled, tarred, or rendered not susceptible to rust by some process: all joints to be calked with lead and oakum, or screw jointed; he will, to insure saving, place as many fixtures as convenient around, and discharge from them into one common stack of soil pipe, which latter he will extend full width and with mouth wide open above the roof, being careful not to bring the mouth below the top level of any living room. The lower end of the soil stack will be trapped by a running or "S" trap, with a hand hole and tap screw on the sewer side, and a fresh-air inlet on the house side of the trap.

The wall outlet of the fresh air inlet pipe he will place so as not to vitiate the air in living rooms should a down draft change the current of air in the soil stack, or else he will run the fresh air pipe into a yard outlet, some eight or ten feet above ground—where applied to detached, or semi-detached dwellings, or in a city dwelling, or flat, he will place the fresh air inlet under the sidewalk next to an inspection chamber: or he will employ a disconnecting trap.

Before going over to plumbing fixtures, we might turn to the respective merits of lead and oakum, and screw joints, the latter being preferable on account of their absolute gas-tight fit. You are aware that only wrought-iron pipe of a certain section can be gas-tight screw-jointed. Moreover, the wrought-iron soil pipes, being driven round a mandril, are almost absolute if not quite equal in thickness throughout—at least they are guaranteed to be so. We also know that cast-iron pipe, being cast either hub or spigot end up, or horizontal, shows in the latter case unequal thickness on the transverse section, and in either of the two other cases on the longitudinal section—a very bad fault if you have to deal with uniform pressure from the shape of the hub, which is by no means uniform. You will see how many chances there are for the plumber to slight his work, even if he has done his best, what becomes of the pipe which is fastened to the uprights or simply, as is very often the case, nailed to a board, which is in turn nailed to the plaster, in case (and it is always the case in frame houses) the framework shrinks and settles. From the nature of the joint in the cast-iron pipe you will also see that, no matter how carefully the joint is prepared, there is an interruption in the run of the inner surface of the pipe, which will hold solid matter—a very serious objection to its use. The same objection naturally arises at each and every joint at connections. All these circumstances go to show that for rigidity, perfection of joints and smoothness of inner surface of pipe cast iron takes in every instance second place, besides seriously injuring the strength of the wooden structure, as in floors, etc. Still another objection to its use is the short length of sections, not much over five feet, by a diameter of three and four inches respectively, necessitating the use of so many more imperfect joints, and multiplying the dangers arising from leaks, while wrought-iron screw-jointed pipe is turned out in sections of 24 feet length each for the diameters mentioned. The heaviest fixtures now in use can be safely and rigidly supported by their connection pipe simply, without needing any support from the floor. In this way the wrought-iron soil stack, with its connections and fixtures from point above roof to junction with sewer may be made a perfectly rigid unit.

The importance of such an arrangement is obvious, and, taken in connection with the fact that wrought iron screw jointed pipe, as described, is of standard section and uniform throughout, makes every case reliable, if such pipes are intelligently placed in a dwelling open to inspection ; all connection with water-closet bowls, wash-basins, bath tubs, wash-trays, sinks and slop-hoppers are fitted with brass nipples. The system described, on which a patent is held by the Durham House Drainage Company, is preferable to any other for durability, safety and facility of repair. I do not venture to predict a millenium in the plumbing trade, or the possibility that everybody might be his own plumber, but the fact is noteworthy that such pipes can be screwed together and set up by mechanics who have not had the advantage of graduating from some plumbing academy, where, it seems, the system of additional multiplication is taught as an introductory to the important knowledge how to wipe a joint.

While it is an often observed recurrence that pipes of too large a diameter are used for soil stacks, it is noticeable that a three-inch cast iron stack, aside from its deficiency in the material, would not be stable enough to independently run through a two or three story house, while a wrought iron stack of such diameter will answer this purpose every time. Such a wrought iron pipe will accommodate all the fixtures in a dwelling inhabited by from six to eight adults. In fact, the number of fixtures should be limited to as few as a family can possibly get along with—say an efficient water-closet, one bath-tub, one washstand, one sink, one wash-tray, and one boiler, to which we may add a slop-hopper.

As to the water-closet, which might be a combined bowl, slop-hopper and urinal, not enough care can be taken in the selection of a pattern. The requirements of modern sanitary engineering will demand that it be simple in its construction, with automatic flush, powerful discharge, and so placed that it may be under constant inspection. Of course, this means that it should not be boxed up, but stand forth in absolute nakedness, with no more woodwork to it than the seat. The best bowls are made of earthenware, porcelain or glass, bowl and trap in one piece. When we remember the pan-closet made of cast iron with all the appendages not necessary to mention, we must admit that great strides have been made since. There is as much difference between the old pan-closet and the all china washout closet with flushing rim, grooved bowl and sure water seal, as between the cast-iron, smooth bore muzzle loader and a steel-bronze field-piece. Yet with all these patented devices an anti-siphon trap, that is, a trap which will keep its water-seal by regular automatic renewal must be provided to such, or any other water-closet, or it will be inefficient and may become dangerous as well as its cast-iron ancestor, the pan-closet. It must be further provided with a seat or bowl-vent and a trap-vent. The latter is the most important one, since, as the name implies, it keeps the contents of the trap exposed to the air current in the soil-pipe. Where there is a never failing and powerful water-supply flushing the trap every time it is used with unerring certainty, such vent might be dispensed with were it not for the column of air ascending at every action of the closet, which air would find

its way into the rooms of the house. While necessity of this precaution is obvious, it should not be forgotten that the room in which the bowl is placed must be kept constantly aerated by means of window ventilators or otherwise—and it is also quite apparent that while a water-closet might be considered safe and well ventilated by itself, the placing thereof off a living room should not be attempted. I would even go so far as to prefer the location of a water-closet bowl in a room entirely by itself, and not in the bathroom, as is the most frequent practice. Since the water-closet and a number of other fixtures discharge into the same soil-pipe, it follows that all such fixtures must be kept ventilated by means of trap-vents and also by so-called back-vents. Washstands placed in or off sleeping or other living rooms need constant care in this respect, and for the perfect cleanliness of all fixtures it is not sufficient to provide them with the devices as described, they must be continually looked after and frequently cleaned in all their accessible parts. Wash-bowl, bathtub and sink waste pipes should be frequently flushed, even when often used, and scoured by means of a hand brush or a brush attached to a wire.

All the benefit surely to arise from the employment of good traps and vents is set at nought if a constant current of air is not made to circulate through the whole system of piping. This is accomplished by the location of a fresh-air inlet pipe as indicated above. This pipe, if properly placed, will keep the inner surface of the soil-pipe exposed to the action of the atmospheric air, and will oxidize the adherent matter. The soil-pipe should be placed so as to leave the house by the shortest route. If this is not possible, sufficient fall should be given it, and all turns should be made by as large a radius as possible. The soil-pipe within any part of the house must be, of necessity, of homogeneous material, and for some distance beyond the same, according to circumstances. Where running through walls it should be arched over or otherwise protected from the pressure of the stonework upon it.

The connection of the soil-pipe with the sewer must be interrupted by the water seal in a running trap, and great care must be taken in this particular. This seal once broken from any cause will admit sewer air into the house, and, according to the location of the connected fixtures, even into living rooms.

Having thus briefly spoken on the subject of soil-pipe connection, I must revert to the matter of boxing-in of fixtures, already alluded to. It is beyond the imagination of a conjurer to perceive the one thousand and one reasons people of average intelligence will give for their favorite idea of the fitness of things in this respect. We cannot very well have a planished copper bath-tub stand out in unchaste nudity, simply because it would become buckled or broken if left so, and not everybody can afford the luxury of an all China or alabaster bath-tub, but for the tight boxing up of any other kind of fixture, there is not the vestige of an excuse. Take, for instance, a kitchen sink. There is no name for the accumulation of all kinds of things that will find their way into a sink box, and the ingenuity of an ordinary housemaid is something wonderful in storing up the most heterogeneous articles in such a receptacle.

Where pipes are in danger of injury if the fixture is left without box-

ing, a wire screen with wide meshes in a detachable frame will sufficiently protect them. The English practice of late is to give pipes and traps a decorative form and nickelplate or bronze exposed pipes. I admit that lead pipes do not range among the list of house decorations, but we must consider that they are articles of necessity, not of beauty, and should they be treated according to their purpose.

I have not touched on the connection of the soil pipe with the public sewer, this being generally a subject within the range of the sanitary specialist.

ABSTRACT OF DISCUSSION OF MR. ROSENBERG'S PAPER, AUGUST 10, 1886.

Mr. Holloway: We have listened with much pleasure to Mr. Rosenberg's paper. You will notice that he recommends wrought-iron pipes. Some people think that wrought iron is subject to greater corrosion than cast iron.

Mr. Rosenberg: We do not run wrought-iron pipe in the ground.

Mr. Barber: Would it not be a good plan to put an open ventilating pipe on the outside wall?

Mr. Rosenberg: It would be better on the inside wall on account of the changes of temperature.

Mr. Barber: Why would it not be a good practice to run a small trap right out on to the roof?

Mr. Richardson: Our City Council passed an ordinance at their last meeting to have such pipes put on their buildings. I do not think that trap would be liable to siphon. Traps that siphon are those connected with long pipes.

Mr. Rawson: A city ordinance requires that the ventilating pipe be connected with the heat flue.

Mr. Richardson: It is not necessary that this soil pipe should draw, or that the sewer gas should go up the pipe. It only provides that the sewer gas should go outside if there is any pressure on it. Sewer gas is formed not only in the street, but may be found in all the pipes in the house. It is well to take another pipe and connect it with the hot-air flue. It is not advisable to attach a pipe to the chimney as it might force gas into the house.

Mr. Rosenberg: Prof. Clarke advises to put all the pipes in connection either with the hot-air furnace or the smoke flue.

Mr. Holloway: The outlets in our sewers are unprotected. It seems to me that a strong wind must produce pressure. They ought to be protected in some way.

Mr. Whitelaw: That is where that ventilating pipe comes in. It has been suggested that swing doors should be provided at the lake end.

Mr. Oviatt: Some years ago all the sewers were provided with protection walls. Swing doors were proposed, but the other plan was thought the better for all those going into the lake on this side of the river. A strong wind increases the current in the main sewer.

Mr. Holloway: On wintry days you notice a current of gas coming out of the sewer. I should think that the sewer should be protected in front to obviate this.

Mr. Oviatt: Some of our sewers are troublesome by reason of sewer gas.

Mr. Rawson: It is customary in some cities to allow this to escape through perforated manhole covers.

Mr. Holloway: That simply divides it, and gives every one a little.

Mr. Oviatt: It discharges all the gas in the main street. It reduces the difficulty somewhat by allowing an outlet in the centre of the city. There is great difference of opinion among sanitary engineers in this matter.

Mr. Holloway: Do they not, in some cities, connect them with some large manufacturing company's chimney?

Mr. Rosenberg: One is to be so connected with a manufactory in Northampton, Mass.

Mr. Richardson: Colonel Waring does not believe in back-vents because he thinks that with them a down draught is likely to occur.

Mr. Rosenberg: Would it not be well to unite as many as possible of these back-vents in a single stack and so make a new architectural feature? The *Decorator and Furnisher* has lately exhibited some examples of exposed plumbing fixtures, making those unsightly appliances decorative features, and facilitating the cleaning of kitchen and pantry sinks by making them detachable from the pipes.

Mr. Barber: It has occurred to me that we might adapt some of the principles of mine ventilation to the ventilation of sewers. In surveying mines I have had my hat taken off by the draught. The minute you open the back door there is a strong draught right into the mine. So there would be into the sewer, if sufficient difference was made between the density of the air in the sewer and outside. The temperature is always warm in the mine. If the air in the sewer was rarified by fans or other appliances, there would always be a draught into the sewer at openings. The mouths of the sewers as well as the ends must be protected.

Mr. Holloway: Ventilation in large mines is produced in two ways, natural and artificial. In the former air goes in at the main entrance. There is what is called a protection wall. The current is always in one direction. The air usually goes in through a downward shaft, is then carried through the mine and goes out at an upward shaft. Where there are many shafts, as in vein mining, special means are required when a little distance from the main current is reached. Sometimes natural currents are sufficient. A draught at the mouth of a drift may be diverted by an upright partition, or a horizontal partition of planks may be constructed along the roof or floor for an airway. The water blast is another simple arrangement. A current of air is blown through square pipes made of boards, or through cylindrical pipes of sheet zinc. Sometimes small fans are used driven by boys or by machinery.

Mr. Barber: There are many large mines where the mine is not level and where the air along the passage goes down grade.

Mr. Oviatt: The upper end of the sewers here is usually from 75 to 125 feet above the outlet.

Mr. Barber: I understand Mr. Rosenberg that it has been the aim to draw air out of the sewer. If air is drawn out some quantity must go in somewhere; therefore, if a sufficient difference of pressure could be produced between inner and outer by rarefying the air in the sewer, ventilation by means of the in-draught might be accomplished.

Mr. Richardson : I think Mr. Barber's method is practicable, if the fans or machinery could be made powerful enough to overcome the difference of temperature.

Mr. Ritchie : Suppose you admit air suddenly, would it not siphon all the traps in the city?

Mr. Richardson : It would siphon the pipes.

Mr. Barber : Whether it would siphon the pipes or not would depend upon the pressure.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

DECEMBER 15, 1886 :—A regular meeting of the Boston Society of Civil Engineers was held and called to order at 7:30 P. M. In the absence of the President and Vice-President. Mr. Thomas Doane was elected chairman. Thirty-four Members and three visitors present.

The record of the last meeting was read and approved.

Mr. George S. Morrill was elected a Member of this Society.

Messrs. W. B. Billings, W. S. Brown, G. W. Hamilton, C. A. Pearson and J. Sondericker were proposed for membership, recommended respectively by D. Brackett, A. F. Noyes ; M. M. Tidd, F. C. Coffin ; S. Perkins, C. E. Putnam ; T. Doane, G. A. Kimball ; G. Lanza, G. F. Swain.

The Committee appointed at the last meeting to consider and report on the communication from the Am. Soc. C. E. presented its report, which was accepted and adopted and a copy ordered to be sent to the Am. Soc. C. E.

On motion it was voted : That four dollars of the initiation fee due from N. H. Crafts be assumed by the Society in consideration of his previous membership.

Mr. Lawrence Bradford read a paper on Hydrographic Surveying.

Mr. Dwight Porter exhibited and explained the Acme Cement Testing Machine,

A discussion followed on the distribution of rainfall by the wind and the mountain ranges of the world, opened by Desmond Fitz Gerald.

[*Adjourned.*] H. L. EATON, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

APRIL 14, 1886 :—The meeting was called to order at 8:30 by President McMath. Mr. Edw. Flad was elected Secretary *pro tem.*

The minutes of the last meeting were read and approved.

The Executive Committee recommended Mr. Jno. A. Sobolewski for election. He was balloted for and elected.

The Entertainment Committee reported that the funds collected for the collation were just sufficient to defray expenses. The Committee was given a vote of thanks and discharged.

No special subject had been provided for discussion. Mr. Bruner presented an original method of preparing stones and cements for testing the tensile strength. Mr. Macklind held a discourse upon the past and present grades of the streets of St. Lou's, and the durability of various asphaltum pavements.

Mr. M. L. Holman explained the construction of the "Curvograph" in its primitive simplicity. General discussion followed.

[*Adjourned.*] EDW. FLAD, Secretary *pro tem.*

DECEMBER 1, 1886 :—The Club held its annual meeting at Mercantile Library, President McMath in the chair, fifteen Members and one visitor present.

Minutes of last meeting were read and approved.

The report of the meeting of the Executive Committee December 1 was read.

The Committee reported the resignations of Jacob Johann and J. L. Stubblefield.

On recommendation of the Executive Committee, Wm. L. Seddon, Benj. F.

Crow, Chas. W. Bryan and Otis Breden were balloted for and elected to membership.

The Secretary then read his report for the past year.

SECRETARY'S REPORT.

Your Secretary respectfully submits the following report of the work of the Club for the past year, including the last annual meeting, and up to the present meeting.

There have been thirteen regular meetings, at ten of which papers were read. The members contributing papers were : T. D. Miller, J. B. Johnson (2), J. A. Seddon, P. M. Bruner, C. M. Woodward, S. B. Russell, R. E. McMath, Robert Moore and M. L. Holman.

Nine new Members have been received into the Club, and eight lost—four having resigned, and four having been dropped from its rolls. The total membership is now 120, of whom 90 are classed as resident and 29 as non-resident, and one honorary. The following statistics in regard to our membership may be interesting. Of the 90 resident Members, 11 are engaged outside of the city, 19 are in the service of the city government, 11 in that of the general government, 10 are connected with Washington University, and the remaining 39 are engaged in various branches of engineering in this city.

The average attendance at the Club's meetings has been 19. All the meetings have been held at Mercantile Library, and at each meeting the President was in the chair.

The most interesting event of the year was the complimentary lunch tended Col. Henry Flad, on March 18, in honor of his election to the Presidency of the American Society of Civil Engineers. The occasion drew an attendance of forty-four members, and was thoroughly enjoyed.

In addition to the committees which report to-night, there are in existence the following :

A committee of five on Smoke Prevention, Prof. W. B. Potter, chairman.

A committee of five on National Public Works, R. E. McMath, chairman.

A committee of five on Fire Streams, Robert Moore, chairman.

The Club was unfortunate in losing the services of its efficient Secretary, Mr. Thos. D. Miller, whose removal to Fort Worth, Texas, was necessitated by his acceptance of the position of manager of the gas works in that city. The office not being filled for some weeks afterward, the present Secretary assumed the duties on short notice, without being initiated by his predecessor. This explanation, he trusts, will excuse any shortcomings that may have been noticed.

Respectfully submitted, WM. H. BRYAN, Secretary.

The Treasurer then read his annual report, which was as follows :

TREASURER'S REPORT.

I have the honor to submit the following report :

Balance as per report of Dec. 2, 1885		$93.00
Collections on account of 1885 dues		134.50
		$227.50
Disbursements on 1885 account		158.45
Balance from 1885 account		$69.05
Dues for 1886 and initiation fees		588.50
Total		$657.55
Total disbursements to date		321.26
Balance on hand		$336.29
Add loan		75.00
Advance on dues		2.00
Total balance		$413.29
Deposit in Provident Bank	210.19	
St. Louis National	200.29	
Cash on hand	2.81	
		$413.29

M. L. HOLMAN, Treasurer.

This report was accepted and referred to the Executive Committee to be audited.

The Librarian submitted an informal report, stating that there had been no happenings of importance in his department. There was no change in the Association of Engineering Societies, except that it continued to improve. Its financial aspect was bright, and it was expected that there might be a surplus to devote to keeping up the Index Department.

President McMath read a report for the Executive Committee. It was accepted and ordered filed.

EXECUTIVE COMMITTEE'S REPORT.

Your Executive Committee is happily able to report at the close of the year 1886 a continuance of prosperity. Membership has increased by the addition of 9 new Members. The losses have been 4 resignations, 4 dropped for non-payment of dues, and none by death ; a net gain of one.

The meetings have been sustained according to the schedule adopted in 1885, with an average attendance of 19. Papers of value and interest have been furnished by 9 Members, in most cases with commendable promptness at the dates assigned in the schedule. Discussion of papers and engineering topics has been more general than in former years, and has increased the interest of the meetings and the profit of those attending.

The support of the meetings by papers, discussions and attendance has largely come from the younger Members. This is as it should be, for it insures an active Club in years to come ; but the older Members need not consider themselves excused from active work in the Club.

The Club by vote has authorized a subscription for one share in the proposed new building of the Mercantile Library Association. Since that project now appears likely to be carried out, the formal subscription should be made. By another year we may hope that the Club may be in permanent quarters favorable to more and better work professionally and socially.

Your Committee have approved the bills for assessments due on account of JOURNAL OF ASSOCIATION OF ENGINEERING SOCIETIES to the amount of $376, and take this occasion to express our satisfaction with the conduct of the JOURNAL.

By the failure of the Provident Bank the funds of the Club were made unavailable, and it became necessary to borrow money to pay bills. The money was loaned without interest by Members of the Club. Its repayment will fall upon the officers of the coming year.

Mr. R. E. McMath, as Chairman of the Committee on National Public Works, made a verbal report. There had been no developments. The Committee was continued.

Mr. Robt. Moore, Chairman of the Committee on Fire Streams, reported reasons for no progress. The Committee was continued.

The Committee to whom was referred the letter from the American Society of Civil Engineers, on the subject of changes in that body, reported having drafted a letter which they recommended being forwarded to the American Society as the sentiment of the Club. The report was adopted, and the officers of the Club were authorized to forward the letter for the Club.

The letter is as follows :

John Bogart, Esq., Secretary American Society of Civil Engineers, New York City, N. Y.

DEAR SIR : In reply to your circular letter of Sept. 1, 1886, asking for the opinion of the Engineers' Club of St. Louis concerning "changes in the organization of the (American) Society," the St. Louis Club has taken the following action :

First.—That as to any organic change in the American Society of Civil Engineers, they do not feel called upon to express an opinion.

Second.—Concerning a possible basis of present co-operation or ultimate union between the American Society and the local societies, which is presumably the

matter at issue, they would respectfully suggest that a union of publications be attempted, which will require no organic change in any of the co-operating societies. Such a common publication would soon result in a better acquaintance and a more intelligent mutual appreciation of the merits and professional standing of the societies so co-operating. If, then, an organic union should seem desirable, it could be more wisely effected, and if such a union should prove undesirable, this fact would appear.

The St. Louis Club would favor, therefore, a *union of publications*, provided this could be effected on an impartial and satisfactory basis. The details of such a scheme do not seem to present any extraordinary difficulties, while the advantages to all parties concerned appear to be such as to warrant a very earnest effort to secure them.

The Committee on Nominations of Officers for the coming year reported as follows: For President, Wm. B. Potter; Vice-President, M. L. Holman; Librarian, J. B. Johnson; Secretary, W. H. Bryan; Treasurer, Edw. Flad; Directors, R. E. McMath and Wm. Wise.

The report was received and the Committee discharged. Further nominations being called for, the name of Charles W. Melcher was proposed for Treasurer. It was then directed that the letter ballot be taken in the usual way.

On motion, the chair appointed Robert Moore, M. L. Holman and Wm. Bouton a special committee to confer with the Mercantile Library authorities on the subject of permanent quarters for the Club.

Chas. F. White addressed the Club on the subject of Furnace Efficiency, giving the results of some tests at the Anheuser-Busch brewery on evaporation and smoke prevention. The subject was discussed by Messrs. Breden, Bryan, Monell, Johnson, Bruner, Moore and Holman.

[*Adjourned.*] WM. H. BRYAN, Secretary.

DECEMBER 15, 1886:—The Club met at 8:15 P. M., at Mercantile Library, President McMath in the chair, and nineteen Members present.

The minutes of the last meeting were read and approved.

The Executive Committee reported the proceedings of its meeting of December 15, announcing the approval of the Treasurer's accounts and the resignation in good standing of W. H. Allderdice, N. C. Bassett and J. T. Desmond.

The committee reported that the letter ballot resulted in the election of the following officers: President, Prof. W. B. Potter; Vice-President, M, L. Holman; Librarian, Prof. J. B. Johnson; Secretary, W. H. Bryan; Treasurer, Charles W. Melcher; Directors, R. E. McMath and Wm. Wise.

The Chair appointed J. A. Ockerson and M. L. Holman a committee to escort the newly-elected President to the chair.

Prof. Potter, on taking his seat, addressed the members briefly, thanking them for the honor conferred upon him, asking their co-operation in furthering the objects of the Club, and assuring them of his desire and intention to do all in his power to make the year one of interest and profit. He then called upon the retiring President for some remarks appropriate to the occasion.

Mr. McMath, in responding, addressed the Club at some length on the present and future status of the engineer, his connection with national public works, and the prospects of improvement in his condition. The subject of compensation was also touched upon, and the advantages of a closer union among engineering societies were pointed out. The address was received with applause, and the following resolution was introduced and adopted:

Resolved, That this Club appoint a Committee of five to consider the subject of a closer connection of existing societies, with a view to forming a general organization.

On motion it was decided that the Committee be appointed by the Chair. The

Committee was constituted as follows: R. E. McMath, M. L. Holman, J. A. Seddon, Robert Moore and Wm. Bouton.

The Secretary read a communication from the Secretary of the American Society of Civil Engineers, acknowledging receipt of the Club's letter adopted at the last meeting. The Secretary also read a communication giving the results of the American Society's inquiry into the subject of changes in its organization. But one society—the St. Louis—had expressed an opinion, and only six of the 763 members addressed had replied.

The Committee on Relations with the Mercantile Library reported progress, and asked to be continued. It was so ordered.

The special order of the day, a paper by Prof. F. E. Nipher, on the "Economic Co-efficient of the Shunt Dynamo," was then taken up. The Professor gave a mathematical discussion of the theory of the efficiency of this class of machine, and showed the conditions under which a maximum was reached. The life and resistance of incandescent lamps was also touched upon. The subject was discussed by Messrs. Flad, Seddon and Bryan. Prof. Nipher also spoke briefly on the subject of discrepancies in measurements of rainfall in gauges at varying heights.

[*Adjourned.*] Wm. H. Bryan, Secretary.

WESTERN SOCIETY OF ENGINEERS.

December 7, 1886:—The 231st meeting was held at 7:30 p.m., Mr. Benezette Williams in the chair.

In the absence of the Secretary, Mr. Liljencrantz was appointed to act as Secretary pro tem.

The minutes of the preceding meeting were read and approved.

Applications for membership were received from:

Mr. Peter Heer, Manufacturer of Surveying Instruments, etc., Chicago, Ill.

Thomas T. Johnston, Assistant Engineer Chicago Drainage and Water Supply Commission, City Hall, Chicago.

Mr. Richard Price Morgan, Jr., Civil Engineer, Dwight, Ill.

Mr. Jason H. Shepard, Contractor, Hyde Park, Ill.

The following gentlemen were elected Members:

Mr. C. F. Carl Binder, Civil Engineer, with W. G. Coolidge & Co., Chicago.

Mr. Bernhard Feind, Assistant Engineer Drainage and Water Supply Commission, City Hall, Chicago.

Mr. John Wilson, Engineer North Chicago Cable System, 86 Lincoln avenue, Chicago.

The special order of business for this meeting, viz., the circular letter from the American Society of Civil Engineers concerning reorganization, etc., was taken up and discussed.

On motion by Prof. Cooley, it was

Resolved, That a committee of three be appointed by the Chair to consider the proposal of the American Society, and report before the adjournment, provided that the Chair be a member of this Committee.

The Chair appointed as the two additional members Professors L. E. Cooley and Hiero B. Herr.

After deliberation, the Committee reported, by offering the following resolution:

Resolved, That this Society is in favor of the organization of a National Association of Engineers, and is convinced that the details of such an organization can be most readily and satisfactorily matured by a conference of representatives of the societies in interest; and

Resolved, That in furtherance of this purpose, this Society is ready at any time

to send delegates to confer with those of the American Society of Civil Engineers and of such other societies as may choose to participate, at such time and place as the American Society may designate.

Resolved, That the Secretary of this Society be instructed to send a copy of these resolutions to the Board of Direction of the American Society of Civil Engineers.

BENEZETTE WILLIAMS.
L. E. COOLEY.
HIERO B. HERR.

On motion, the resolutions were adopted.

A letter from Prof. I. O. Baker was read and on motion of Professor Cooley was referred for consideration and report at the next meeting to a committee of three, to be appointed by the Chair. The Chair announced that the Committee will be appointed and notified through the Secretary.

A paper from Mr. Charles Latimer on "The Metric System" was read. On motion, this was referred to the Trustees for consideration.

[*Adjourned.*] G. A. M. LILJENCRANTZ, Secretary pro tem.

ENGINEERS' CLUB OF MINNESOTA.

OCTOBER 8, 1886:—Regular meeting. Present, Mr. James Waters, President pro tem.; W. W. Redfield, J. H. Barr, G. W. Sublette, and W. S. Pardee.

Reading of previous minutes was omitted.

The Secretary stated, on behalf of the Committee on Permanent Quarters, that rooms could be had in the new Library Building. No action was taken.

On motion, Mr. G. S. Houston was elected a Member of the Society.

The names of M. J. Rigg, Geo. Caven, F. W. Capelen and C. L. Redfield were proposed for membership by Geo. W. Sublette and Wm. W. Redfield.

On motion of Mr. Sublette, the mailing list of subscribers to JOURNAL OF THE ASSOCIATION was ordered revised, so that Honorary Members be omitted as beneficiaries of the JOURNAL.

[*Adjourned.*] W. S. PARDEE, Secretary.

DECEMBER 10, 1886:—Regular meeting. Geo. W. Cooley, President pro tem. Other Members present, W. W. Redfield, Jno. Barr, Geo. Sturtevant, W. S. Pardee, Geo. W. Sublette.

Previous minutes were read and approved.

On motion the Secretary was instructed to notify delinquent Members that the six months' limitation having passed, said members were liable to be dropped from the rolls.

On motion, Jno. Lamb was exempted from all dues.

Messrs. C. L. Redfield, Geo. Caven, M. J. Riggs and F. W. Capelen were elected Members of the Club, and the name of P. B. Winston was presented for membership, certified to by W. W. Redfield and G. W. Sublette. Club discussion took place on the topic, "Do Surveyors' Bench Marks on Trees Rise with the Growth of the Tree."

[*Adjourned.*] W. S. PARDEE, Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

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HYDROGRAPHIC SURVEYING.

By Laurence Bradford, Member of the Boston Society of Civil Engineers.

[Read December 15, 1886.]

My purpose in this paper is not to write after the manner of a treatise on hydrographic surveying. I have no intention of following step by step through the processes that lead up to the practice of this art. I shall speak of what has come to me in my own experience, and the methods I have followed. Some of these are original, so far as I know, but I am not one who believes in employing a poor method of my own device, when a better one can readily be had from some one else. That other and better may exist is not my province to deny. One of the Institute professors once said to us in the class, " Can you, if called upon years hence, cipher out the problems that may come relating to this matter? I will not ask that you shall be able to do them in the best possible way, but will you be able to do them in any way?"

I do not remember ever to have seen a book that treats of the subject in all its parts, or one under this name, though many papers and reports have been published that treat on certain branches; particularly the Coast Survey reports. These and others I shall allude to as I go on. An experience in this work I have certainly had, because from my earliest boyhood I have been connected more or less with work on the water. So I intend speaking of the methods followed by seamen in making their locations, taking their departures, etc., which, without doubt, is closely related to, if it is not a part of the art of hydrography.

Following along, I must and shall touch upon matters with which you are thoroughly familiar, but not with the idea that you do not understand them, but to bring them to your mind in connection with what I have to say.

When any hydrographic survey of whatever extent is to be made, the tides must first be taken account of. To the scientist they are an interesting and complicated study, but to the surveyor their use ordinarily is limited to furnishing a water level and datum plane, and it is only in this line that I shall comment on them. For a small work, explaining their main characteristics in different localities, I would refer you to

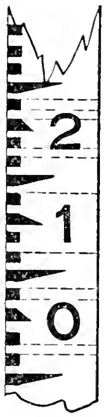
a pamphlet by a member of this society, Prof. Henry Mitchel, issued by the Coast Survey Office some years ago, and prepared principally for the use of naval officers. A datum plane is of necessity the basis of all this work. If the water did not fall or rise it would be *sea level.* You know this is often taken now for land surveys, and for that purpose is probably the best of all datum planes, if for no better reason than this interesting fact—that it can be ascertained very nearly at any time by taking the mean between the low and high water of any one tide. The other datum planes cannot be so readily obtained. *Mean low water* is the one generally adopted for all hydrographic work, though the *lowest low water* has in times past been very considerably used, principally for the reason that navigators might know that soundings as shown on the charts could always be relied upon as giving at least that amount of water at the place indicated. But while there is some force to this way of looking at it, it has come to be acknowledged that the best plane for all purposes is *mean low water*, from which the lowest low water is easily at any time found. To obtain this, the tides should be taken through one *Lunation*, one revolution of the moon, and this is given in fifty-seven low waters by taking the mean of them. It is usual to take the high-waters, also, that the usual features may be tabulated—mean rise and fall of tides, establishment of the port, etc. It would give a nearer mean to take the tides for a whole year, but not much. You may ask, How much ? To this I can merely state a single experience of my own. While engaged in this work in San Francisco harbor I made a comparison between a *mean low water* obtained from a lunation, and one that had been ascertained by a consecutive record of tides reaching through fifteen years, and the difference was something like thirteen hundredths of a foot, of some value scientifically, no doubt, but hardly to be considered in this work as very important. This record, kept continuously, was obtained by clock-work machinery. Section paper unwound from one roll to another at a rate that took in a convenient length of paper for twenty-four hours. A pencil controlled by a simple mechanism attached to a float of the tide gauge gave the rise, fall and duration, by the wavy line you have seen used to graphically represent the action of the tides. These are well shown in the earlier Harbor Commissioners' reports of this State, with the effects that obstruction to the free movement of the tides, have upon the curves. One curious circumstance they showed me on this record of past tides. Some time before there had been an earthquake of great force on the coast of Japan, the time of its occurrence there had been noted, and the time the tidal wave reached this place was here shown on the tidal curve, in sharp zig-zag lines. I suggested that these might be caused by the quick movement of the waves in stormy weather, but they showed me that the lines made by the sea were not the same.

The gauges I have used have been of only two kinds, the simple staff and the box gauge, shown in Plate I. I think the staff answers the best. Like a self-reading leveling rod, it can be marked off as the fancy of the observer may dictate. I only care that the parts of the figures be in such relation to the *tenths* that the height of the tide can be told as far as the numbers can be read with a glass. In the box gauge, the figures neces-

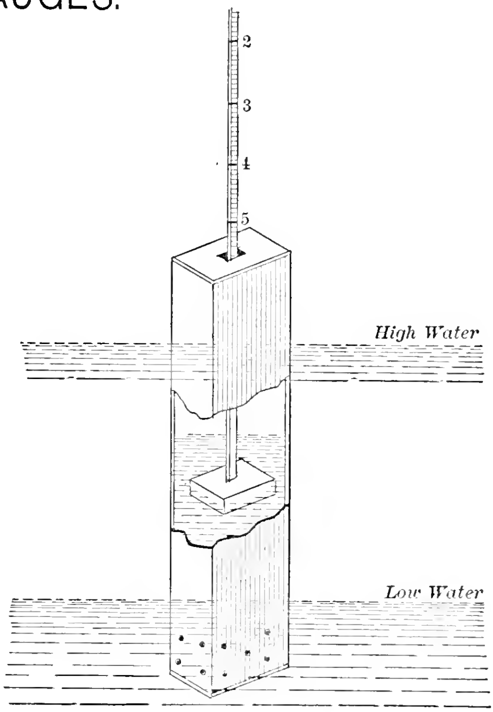
sarily run from up, down. And to work up data from it, the length must be known from the zero of the graduation to the water line of the float.

Plate I.

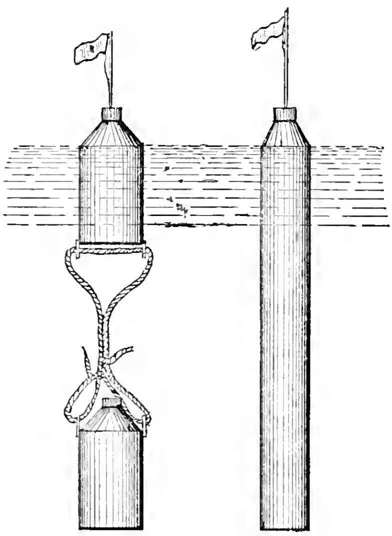
TIDE GAUGES.



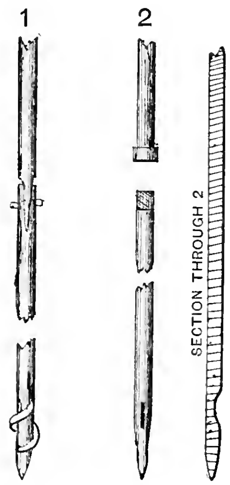
STAFF.



BOX.



FLOATS.



SOUNDING IRONS.

While the hydrographic survey can be made sketchy or elaborate, one of the former kind costs less to make on the water, and one of the latter

costs more than the same on the land. And yet the one of the prelimi nary nature made on the water is more valuable than the same of the topographical kind, for the reason that the element that has furrowed and cut up the surface of the one has tended to even the bottom of the other.

The skeleton outline of hydrographic work is obviously triangulation. The base line being chosen in as commanding a position as possible, the other stations may be *cut in* from its ends, without the calculation of triangles, or the other points may be occupied and the triangles completed. Points not occupied, it is hardly necessary to say, are fixed by a considerable number of intersections.

These stations, if they are to be used for getting sextant angles, are best defined by the spires of old-fashioned meeting-houses. They are rather to be preferred to show against the sky to the observer; but as they are generally painted white it does not make so much difference. The lines of soundings it is now customary to take as evenly as possible, making them cross so as to form regular geometrical figures. when their usefulness is not sacrificed, as they look much better when plotted.

The lines of soundings should frequently intersect, as on their *well crossing* lies the best proof that the work has been well done. If the sheet of water is nearly emptied by the tide, the low water channels can be quickly and well defined by *zig-zagging*, as it is called; that is, running over them after the manner of a Virginia fence, when the tide has left the harbor.

The implements I have used for borings are shown on Plate I., made of gas pipe ½ inch to 1⅝ inches diameter. A craft made for the purpose, with a well in its centre, or platform running out from its side, where tackles and purchases can be applied, answers best for these operations. I have never had much difficulty in getting the rod down to any depth required and ascertaining the quality of the material penetrated, but in getting the rod out has been the trouble. When not fitted out as above described a good way of applying a persuader, when meeting with an obstinate case, is to moor two boats, the sounding iron between them. Then place across the boats a small boat's mast; fasten to the sounding iron a foot or so below the surface a single or double line, the other end wound around the boat's mast; use this as a windlass. This power, with the help of the tide in a bad case, I have always found effectual.

The best method I have followed to take the speed and direction of tidal currents I think to be this: A simple tin can is loaded with shot or stone till the top is just above the water. This is for the surface current. If it is desired to know the mean current, sink a similar can below the floating one connected by a line; or a long single line can be used as shown in Plate I.

Place yourself on the position where you wish to begin; take the time to seconds and let it go. After it has gone far enough, or changes its course, drop a floating buoy with line and weight attached alongside of it, at the same time taking the time. This buoy can then be located, the float followed up, and the operation repeated.

I will now speak on the location of positions or points, principally the theory and practice of locations by sextant angles, on which I would devote the most of my time.

On this question, might be said to hang my main subject and everything pertaining to it, just as in religion we are told on two simple commandments hang all the law and the Prophets. If the line of soundings is long, points on its length must frequently be established, otherwise the plotted soundings will not represent the place where they are shown.

A good, perhaps the best method of doing this, where a suitable range can be had, and the conditions are otherwise favorable, is to *cut in* the soundings from a point on shore with a transit instrument, placing it where the intersections will be good ones throughout the length of the line. It is well to take them at equal spaces of time apart, for then can be seen how evenly your boat has moved on the course. The recorder of the soundings, having a watch in his hand, gives a signal to the leadsman as the second hand approaches the minute. The leadsman raises his hand, and the intersection is made. Another method is to have no observer on shore, but to take one angle with a sextant from the boat at the points desired, choosing the stations observed upon in such relation to your line of soundings as to vary rapidly your angle with the moving of the boat. If you are not running a continuous straight line, at the point where the direction changes two angles would have to be taken, requiring two sextants and two observers in the boat. The principles of this method I am going to discuss further on.

Sometimes lines of soundings are run between known positions without being *cut in* along their length, and the only way taken of adjusting the individual soundings is to check off equal spaces of time, the same as I have described in connection with transit intersections. These are called time soundings, and are based on the assumption that the boat has moved over equal distances in equal times.

THE SEXTANT.

I am going to keep along on the same subject, but make a sort of a side show in speaking of this instrument, which alone is made use of in locating positions by the method I shall describe.

This is the most satisfactory of all surveying instruments, within its limitations, and is indispensable for hydrographic work. It is readily carried in the hand, does not need a stable foundation for the observer, and can be used at a minute's notice, taking angles, vertical, horizontal or inclined; and reads readily to ten seconds by its large arc. Its main characteristic is, that it takes its angles by a mirror, on the principle that the angle of incidence is equal to the angle of reflection. There are two mirrors, one that takes the angle and is secured to the arm that has the vernier. The other arc is fixed and brings the reflected image to the eye. By this double reflection the arc that the vernier passes over is only one-half the angle really measured. The arc is the sixth of a circle, hence its name sextant; while according to the principle above, it can measure an angle of 120°.

It is a curious fact that this instrument was invented by two men at nearly the same time, unknown to each other. One, the famous Newton; the other John Hadley, who made it known, and to whom is given the honor of its discovery. It can be put to uses outside of what might be called its legitimate work.

When vessels are on the same course it can be used on board, either by taking an angle from the main mast truck to the water line, to tell whether they are approaching or separating, a difficult matter to judge by the eye, when in this relation to the distance to be estimated. It is said on board slave ships in old times, when they were pursued, that when the sextant angle began to grow larger, they began sawing through their deck beams. In reconnoissances on horse-back, when it would be inconvenient to dismount, an angle or location can be taken from the saddle. Lieut. George H. Mendell, of the Engineer Corps of the army, now Colonel, published some years ago an interesting book on this instrument.

Location by sextant angles is the main method in hydrographic work. The intersections that determine the locations are made by the crossing of circles whose circumferences pass through three fixed points, the middle one common to both circles. These fixed points, here called stations, may be in many possible positions relative to each other and to the intersection point, but the relationship determines their worth to a marked degree, many cases being wholly valueless. If the station and intersection point are in the same circumference, there can be no approach to a location, as the angles, without changing, will whirl around the circles, and no good location can be made even near to this circle. It is often given as a rule that the sextant angles should not be less than 30° or more than 120°. I would have them not less than 40° or more than 100°, but angles within these limits may be used and still the location not be good one, if the crossing of the circles do not make a good intersection; and vice versa, the crossing of the circles may make a good intersection and the angles not be within these limits, when the location would be a poor one. I have given four cases in Plates II and III that will with modifications cover all good cases of location. Taking Fig. 1, Plate II., if the stations *A*, *B*, *C* are in this position, the outer stations at each end of a diameter of a circle and the central one 90° distance in the same circumference, and the intersection point say in the centre of the circle, you have the best possible location; but the locality would be rather an uncommon one to allow choosing the stations in those positions. The field of operation too is small, as given in the broken hatched lines; not even so much area as the 40° to 100° limit angles would cover, the intersection of the circles becoming poor before these limits are reached.

Take the stations as placed in Fig. 1, Plate III. These, I consider to approach the best, placed as they are in the circumference of a circle sufficiently large not to hazard any risk of the location point being near it, and yet enough of a circle to make an extended area for work. In Fig. 2, Plate II., the stations are in a straight line. This is a convenient arrangement at times. There can be no circle passing through them and the intersection point. At the same time the field of operation is small. This is increased very much by making the limit of angles 30° to 120°, as shown by broken hatched lines crossing the others at right angles.

The station can also be in a circle curving slightly outward, but the field of operation is made still smaller, The stations at equal distances

are best; not a measured, but an approximate equality. I have shown in Fig. 2, Plate III., the extreme stations at unequal distances from the

Plate II.

Fig. 1

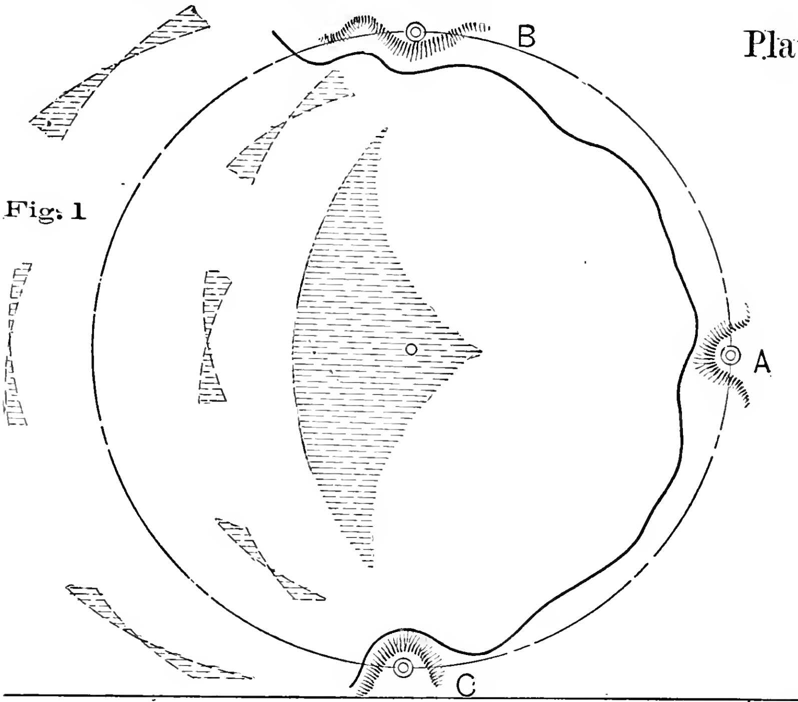
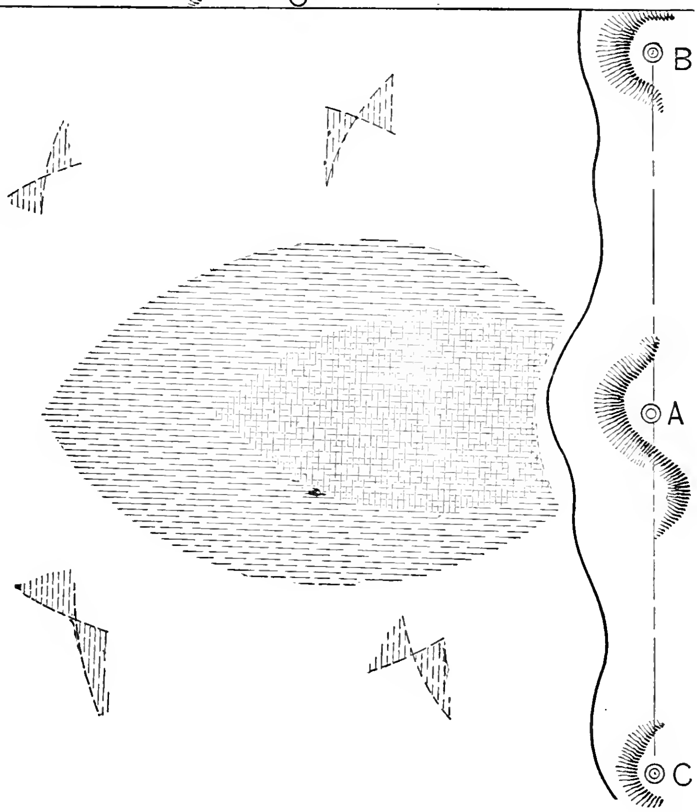


Fig. 2



central one. The important effect of this is the shortening up of the field of operation.

These remarks can be condensed and substantially expressed by these simple propositions.

1. That the sextant angles be not less than 40° or more than 100°.
2. That the stations be about at equal distances apart.
3. That a point midway on a line connecting the outside stations be not more distant from the central one than it is from the outer stations.
4. That the location or intersection point be not near the circle passing through the stations, nor outside of it.

It is not pretended that these remarks or rules will strictly apply to surveys of all natures and all areas in some instances.

They might well be thought to draw the question a little too fine ; but when it comes to reverse the process and refind upon the water certain features that have been shown by the plot, or to reproduce many times the same points and define the elevations of submarine rocks or ledges, they will not be found, I think, to have carried the discussion to an unnecessary degree of precision.

To reproduce any point that may be required after a survey has been made, is not so easily done as to make the survey in the first place. It is, however, then ascertained how well the stations have been chosen and the work has been done. To reproduce these points requires some mechanical dexterity, gained by practice, learning to direct the movement of the boat that the images of the stations will close in the mirrors of the sextant in a short space of time, as surveying in this line has commonly to be done at smooth and slack water, sometimes after weeks of waiting, so that little time can be spent in fixing a single point.

Two sextants are required, one in each hand, the left-hand one set to the angle for *B* and *A* ; the other with the angle for *A* and *C*. When the point is found it is usually marked by a floating buoy, if for temporary use. If needed permanently, by a pile or anything desired.

In plotting these angles, I have followed three ways. The best, undoubtedly, is by an instrument called a three-arm protractor. It is a graduated circle, much like a transit instrument plate, commonly of six inches diameter, its centre so constructed that the central point may be observed and marked. About this revolve the two movable arms on each side of a fixed one, at the zero of the graduation. These arms have lengthening parts, screwed on or removed at pleasure. An instrument of this kind is expensive, and not always easily obtainable. Another method is by a graduated circle of a foot or so in diameter, engraved on tracing paper. The angles are laid off in pencil on this and moved to the spot. The most inconvenient part of this method is, that the pencil marks must be rubbed out after each point is plotted, or they will confuse the work. Another method I have found very convenient, where much work was to be done from one set of stations. Plate IV. Lay off from the extreme stations *B* and *C* graduated arcs of radii that seem most suitable for the matter in hand. The zero of the graduation will be on lines at right angles to *BA*, *CA* from *B* and *C*. Bisect these lines *BA*, *CA* and lay off perpendicular. Having sextant angles to plot lay off the one that takes the stations *B* and *A* from *B*. And take the point where it intersects the perpendicular for a centre and describe a circle that passes through *A* and *B*. Do the same for the angle that takes the

stations *A* and *C*. The intersection of these circles will be the location. The proof of this operation you will readily see.

Plate III.

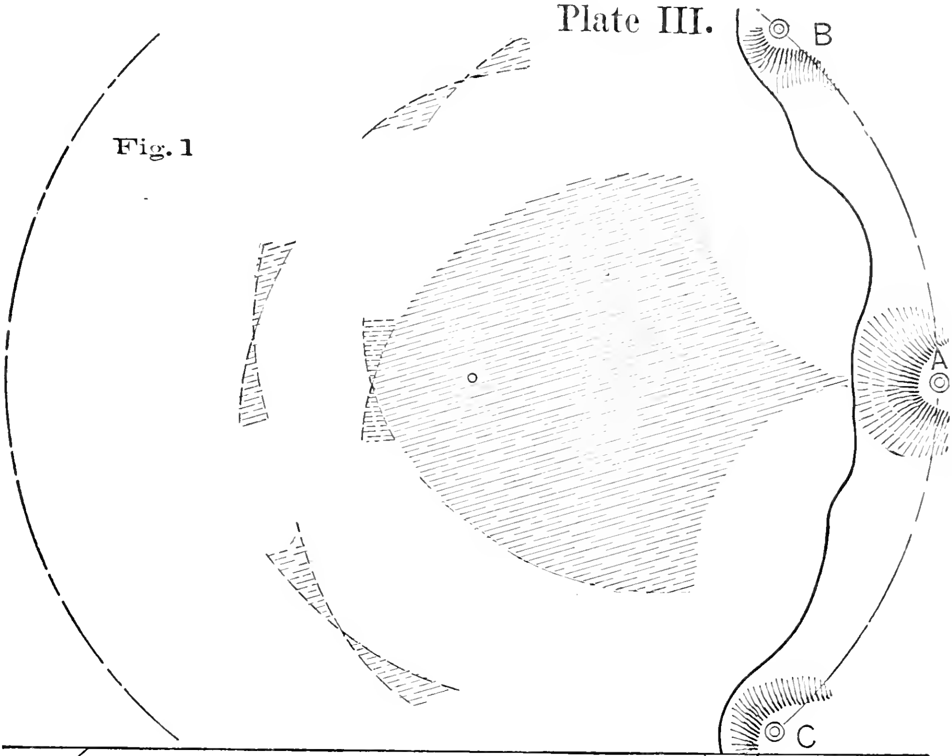


Fig. 1

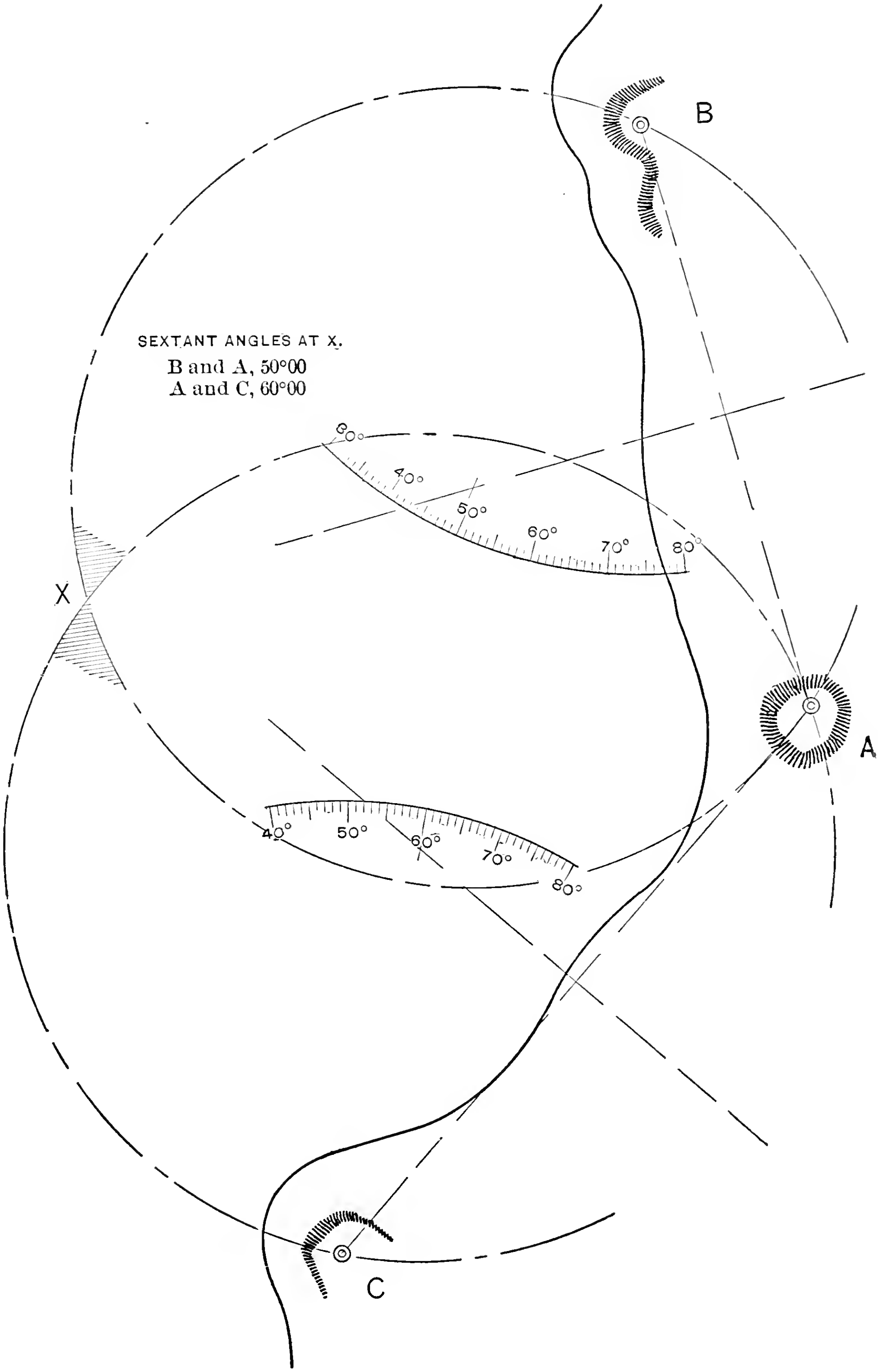
Fig. 2

On Plate V. are shown the ways I have followed in surveying rocks or ledges. Fixing a boat at *A* and running soundings, either in circles at

regular distances, or in lines at defined angles. A good way to locate a point without survey of any kind is by ranges, taking two sets at about right angles to each other, for, if well chosen, they have the precision of sextant angles. The difficulty is, in not being near enough to the shore to obtain good objects, principally to get the first one sufficiently near. The advantages of this method of location were first brought to my notice, as well as a way of clearing out channels, since common enough, but then at least new to me, on the James River just after the capture of Richmond. I was then attached as second in command to a dispatch boat that plied between City Point and Fortress Monroe, and the first vessel to enter Richmond at the time of its capture. The river was then found to be full of obstructions, and it was judged of torpedoes, as they were seen in heaps along the shore between Bermuda Hundreds and the entrance to the city. At once operations were entered upon for clearing the channel. A military engineer was assigned this duty and our vessel was placed at his disposal. He had tin cans made, holding from three to ten gallons. These were filled with coarse powder found in the abandoned magazines of the rebel works along the river. The engineer officer would feel over the channel at the shoal places, with a sounding iron, judge what the obstructions were and the best place to sink the cans, locate himself by two sets of ranges. When he found the best place, a can was then sunk at this place and exploded by a galvanic battery, when the obstructions, mostly sunken vessels, were thrown out. The Fish Commissioners in their late report give a method of making their location at sea, making no pretension to novelty. In a telescope having microscopic lines, they take the spans of natural objects like mountains, but principally light-houses, all the altitudes of which are given in the Light-House Department manuals. They take at the same time a compass bearing. I have at times followed a method of this kind for the determining of points of secondary importance, usually short lines, with the needle of a transit instrument taking three compass bearings on three of my fixed stations. They can be plotted the same as if taken by distant angles, or they can be plotted as compass courses.

You may ask, "How is a sunken rock found, as you do not pretend to go over the whole bottom when making a survey?" To this I would answer, that they are often found as the Irish pilot found one. To the question if he knew the harbor, replied, "Yes, and every rock in it;" later, when the ship brought up all standing, "and this is one of them." The smaller class of boats, lobstermen and fishermen, usually first find them, and report their whereabouts, sometimes with ranges for locating them. Of these ranges and the area they will cover, "custom cannot stale their infinite variety." There is not often much discount about there being a rock or ledge at the given depth of water, as quite likely they have got this information by an impressive and uncomfortable experience. Once, while working in Maine, I had direction from the military engineer officer, by whom I was employed to look up and survey a ledge of rock that some shipmaster had reported, saying that they would show me where it was. Although the place was an estuary not more than two miles across, they could not place it within a quarter of a mile. I explored all round with a sounding iron, but could not find it

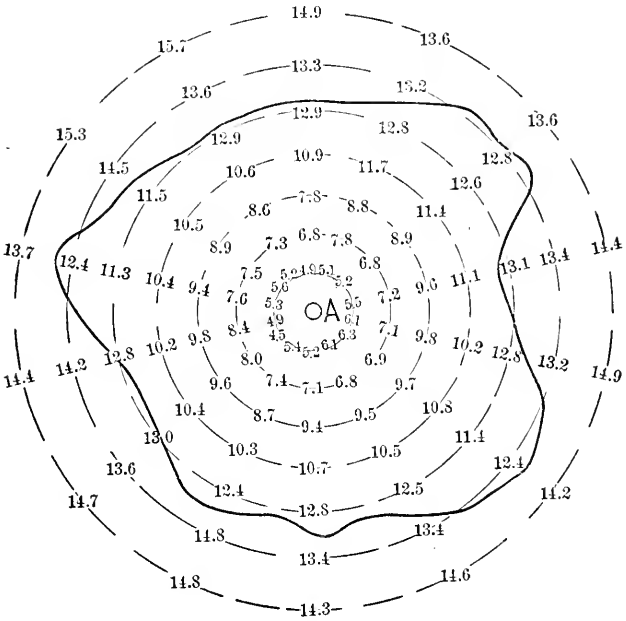
Plate IV.

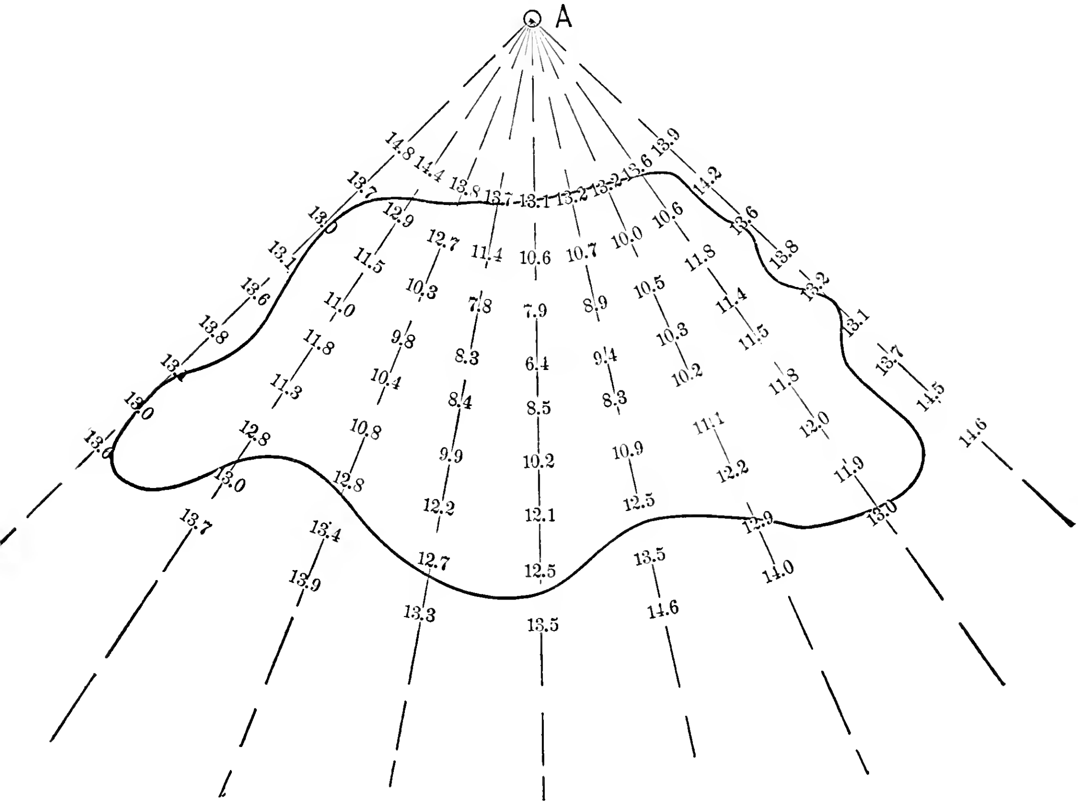

SEXTANT ANGLES AT X.
B and A, 50°00
A and C, 60°00
B
A
C
X
30°
40°
50°
60°
70°
80°
40°
50°
60°
70°
80°

till later, with a dredging machine; it was found with gravel and small stones covering most of its surface. A person skilled in the matter will tell a sunken rock by watching the break of the waves over it, when there is the right amount of wind and sea. I have known rocks of no great size to be found in this way a number of feet below the surface. I will speak now briefly on the navigation of vessels, and the methods they use. Those cruising along shore, like the boats to the Southern ports—and the same might be said of the trans-Atlantic lines that follow one pathway—can be almost sure of making their runs without accident. I hear you say, "How about the 'City of Columbus?'" but I will pass on. When leaving port they take from a certain fixed point, like a lighthouse, a compass bearing, estimating the distance, or two bearings are taken to fixed points shown on the chart. This is called taking a departure. This point is plotted on the chart and a course laid out to the next point it is desired to make. The variation of the compass is then allowed for and the corrected course given to the quartermaster, or whoever the man may be that steers the vessel. Many a ship has been lost by putting this correction on the wrong side. With the patent log now in use the distance run can be nicely made *with care*; that is where it all comes. What the plumb line is to the engineer, architect or mechanic, the sounding line or chain is to the hydrographic surveyor or navigator, only with the latter class it is not enough used, and simple though it may seem, they do not generally know from want of practice how to well use it, outside of smaller craft like fishermen, and the war vessels. If beyond the sight of land the methods of obtaining the latitude and longitude must be employed. If a vessel's position is determined within a mile after being out any length of time it is considered fine reckoning. The ways followed are not hard, but the *be sure you are right* qualities are needed. These calculations were ciphered down to their simplest elements by the grandfather of one of our fellow members, Nathaniel Bowditch, who, although a renowned mathematician himself and one who had hung to his name a long list of learned societies, appreciated perhaps more than any one who ever prepared a practical or working treatise the necessity of placing his methods within the comprehension of the class of persons for whom they were intended. He expected his auditors to know next to nothing, and he was not always far out. The longitude is found by taking an altitude of the sun, at about nine o'clock in the forenoon or three in the afternoon, a time when it moves the fastest to the eye of the observer. At the instant the altitude is noted, the time of the chronometer is taken, and on the niceness with which this is done depends the accuracy of the position. This altitude worked up by a formula gives the time of day as given by the sun; it is converted into mean or clock time. The chronometer gives the mean time of Greenwich or any other meridian. The difference is the longitude. The latitude is obtained by an altitude of the sun, when on the meridian, and is found by a calculation even more simple.

While the principles required are few and plain, and the manipulation easy, the details to be mastered, and practical skill, are by no means inconsiderable. It is not a training that is gained in the schools, which, to

Plate V.





a certain extent, be it more or less, make an engineer. Among the uneducated are often the most skillful; that is, those who do not lose their vessels, if only their bump of observation and locality is abnormally developed.

Have you not met in your railroad surveys men whom it was nearly impossible to lose, or turn around, in darkness or stormy weather? They have the qualifications that make a navigator.

ENGINEERS, THEIR RELATIONS AND STANDING.

AN ADDRESS.

By Robert E. McMath, retiring President of the Engineers' Club of St. Louis.

[Delivered December 15, 1886.]

Two topics bearing upon the interests of engineers have engaged more or less attention on the part of this Club during the past year; one, the relations of civil engineers to national public works; the other, the relations which should exist between engineer societies. Consideration of these topics might well, if time permitted, be extended to the more comprehensive subject—the position of engineers as a profession in the United States.

Discussion of the relations of civil engineers to national public works is rendered somewhat delicate, as seeming in the eyes of some to be little more than a controversy between civil and military engineers over the control of national works in which the latter class have the advantage of being in possession of the object of dispute. In no proper sense is there occasion for such a controversy, The questions involved are not concerning the interests of one class as opposed to another, nor of the personal fitness of those who now exercise the functions of government engineers.

The real questions were temperately and forcibly presented by L. E. Cooley, of the Western Society of Engineers, in his paper on "A Rational Policy of Public Works," published in the Journal of the Association of Engineering Societies. He showed the need for a rational policy of public works and for a special service organized for their conduct. His position is unimpeachable, that the adoption of a policy, the recognition of the utility of and necessity for a system of public works, must precede the provision of a special service. This must not be understood as suggesting that the elaboration of a system to a formal scheme on paper, or even a catalogue of works to be done, should be preliminary to such an organization; but rather that the measure and importance of the works required must be recognized before the necessity for a special service can be apprehended. When a growing town finds that it must have streets and drainage of some sort, it is likely to employ some resident who can handle transit and level, a make shift of an engineering department. But when the need comes and a determination is reached to have the best streets, water-works and sewers, then it is generally

understood that the engineering department must not be made up of such material as may chance to be at hand, but competent men must be sought and adequately paid; that is, the need demands a special service.

Originally public works by the general government were not contemplated. Necessity compelled that some should be undertaken. There being no policy, a provisional arrangement was resorted to which answered for the time and has been continued until now. But the country has grown and its needs have been developed. The preliminary determination to have a system of national public works has been reached, after a long discussion of constitutional limitations, State rights, etc. I am persuaded that the determination has also been reached that the system shall be liberal in extent, shall be persistently carried out, and that the works shall be the best of their kind in plan and execution. The time has therefore come when consideration of the matter of an organization—a national engineering establishment—is appropriate and necessary. Naturally the first movement in this direction must come from engineers who know from experience the defects of the provisional arrangement.

But, it may be asked : Since we have an organization, an engineer bureau already, what more is wanted ? And why ? These questions are reasonable and must be answered.

The answer in general is : The Engineer Bureau, U. S. Army, was primarily created for a particular purpose and that purpose was military ; that the assignment of civil works to a military bureau is mixing things which are incompatible by nature, but was done when the nation was in its infancy, when our territory was much smaller than now and mostly unsettled, when the extent of civil works was not apprehended or their nature foreseen, when engineering was scarcely recognized as a profession, much less as a profession divided into distinct branches. Such assignment as a provisional expedient was perhaps as good an arrangement as could be made at a time when the right of the general government to engage in public works within the boundaries of the States for the benefit of commerce or the every day convenience of citizens was in question, when the territory was possessed but in name and needed first to be explored and hostile tribes dispossessed before civil works could begin.

In the development of human history the warrior precedes the citizen, the artisan for a period waits upon the soldier, but in time these relations are reversed, the citizen employs and supports the soldier. But the old traditions survive in a degree that warrants the assertion that civil and military duties are incompatible if mixed. The soldier is still inclined to look down upon the civilian, to prefer the title of General to that of President, and hence to regard the work of a civilian as degrading drudgery. This feeling was curiously illustrated when the U. S. service had two classes of engineers, engineers and topographical engineers, the first regarding the latter as inferior, though of equal rank, sometimes officially superior. The feeling continued after the bureaus were consolidated, and expired only with the generation of topographers who were absorbed. The same traditionary feeling manifests itself now in the association of civil engineers with military as employé and employer.

The civilian is treated as one to whom a meagre allowance of rights and privileges need be accorded and of credit for his work none, if his superior chooses to absorb it.

It has been said that "Except by custom and implication army engineers have no legal or legislative status for civil work and may be considered as virtually on detached duty." That this is not strictly accurate will appear from the following citations taken from an official document, "A Historical Sketch of the Corps of Engineers, etc." Washington, 1876.

The act of March 16, 1802, Section 27, provided: "That the said corps when so organized shall be stationed at West Point, in the State of New York, and shall constitute a Military Academy, and the engineers, assistant engineers and cadets of said corps shall be subject at all times to do duty in such places and on such service as the President of the United States may direct."

As a light upon the interpretation of this act, from report of Secretary of War McHenry, January 31, 1800: "We must not conclude from these brief observations that the service of the engineer is limited to constructing, connecting, consolidating and keeping in repair fortifications. This is but a single branch of their profession, though, indeed, a most important one. Their utility extends to almost every department of war, and every description of general officers (offices ?) besides embracing whatever respects public buildings, roads, bridges, canals, and all such works of a civil nature."

Duties of a civil character were subsequently assigned to officers detailed from the engineer corps. March 3, 1851.—"To superintend the construction and renovating of light-houses." March 2, 1867.—Superintendence of Public Buildings of Washington Aqueduct "and all the public works and improvements of the United States in the District of Columbia, unless otherwise provided by law." June 30, 1874.—Engineer of District of Columbia.

From the foregoing it appears that the design at the beginning was to employ the engineer corps for general duties, civil as well as military, and that the law warrants such employment, hence the matter for consideration is not concerning the past or present but the future policy.

Returning to the inquiry, what more and better is needed than the present organization affords? and why? I would say:

First. That the Engineer Corps, as established by law, is insufficient in numbers to perform the duties assigned it; hence civilians are and must be employed until further legislation is had. That this employment of civilians is not relished by the Engineer Bureau is abundantly shown by the repeated recommendation of the Chief Engineer that a greater number of subalterns be authorized "to take the places of many of the civil assistants we are now forced to employ." The civil assistant, as Mr. Cooley and others have shown, is not at ease or content with his position, which has no legal warrant whatever. Civil engineers in and out of government employment, and the Engineer Corps itself, are therefore of one mind as to the desirability of a change. And as yet there is no antagonism over the nature of the change.

The Engineer Bureau asks that it be by increase in number of the existing oorps; the civilian side, though not favoring this proposition,

has never formulated any alternative plan. The discussions and conventions held during the year disclose an unexpected want of distinct purpose or desire, an inability to formulate anything. So long as this is the case, it is useless to look for result. For one, I am not unwilling to accept the bureau's proposition to build upon the existing foundation, only I would specialize the service, dividing it into distinct branches, and separate it as an administration from the War Department, for the following reasons :

First. The range of duties now required of engineer officers is so varied that it is impossible for any man to be thoroughly familiar with all, and yet he is liable to be assigned to any. Indeed, in due course of rotation in station he is supposed to traverse the whole round. Duty with troops, staff duty, fortifications, surveys—topographical, hydrographical and physical—civil works on rivers and harbors and lighthouses, electricity and its applications, with a chance at municipal engineering—sewers, streets, water-works and buildings.

There is no division of opinion as to the possibility of any man mastering all these diverse duties, even in the sense of preparing him to direct or administer any of these departments. Of course, an engineer worthy of the name must have an intelligent acquaintance with all branches of his profession, in a somewhat broader sense than he must have with literature, art, and science, and the young man is unwise or unfortunate who adopts or is shut up to a narrow specialty until he has gained some practical acquaintance with other work. The engineer, more than the artisan, needs first to know how to do many things, then to bring his knowledge to bear upon doing one or at the most a few things well. Under the present organization of the Engineer Corps, specialization is not aimed at or as a rule practiced.

Second. The traditions of military service are not favorable to the development of an engineer of the kind that the country needs. By that tradition the engineer is limited to an executive function only. He is to do the best he can with the means put in his hands, but is to be chary of suggestions or opinions unless they are officially asked for, and he must avoid saying or doing anything to influence legislation, or to mold congressional or public opinion, lest he cross the purposes of his official head. He loses too much of his individuality. Again, the power of military discipline may be again, as it has been, exercised to repress investigation, and so to block professional progress. Not always will an Eads and a jetty controversy opportunely appear to break the fetters.

Again, the military organization lacks the quality of elasticity by which work is intrusted to him who can do it best. Its members must come from a particular school, and by a certain course of routine after the school course ends. The ablest engineer living, if not belonging to the corps, cannot be given charge of government work, even though every member of the corp should admit unfamiliarity with the work in hand. The brightest and best man in the corps is equally shut out from charge unless he has completed his round of service, and by successive promotion has attained a certain rank.

While, as I have said, I would be willing to build upon the existing foundation, my preference would be for something like the following :

Make national public works a civil service under a bureau of public works whose chief shall be selected, much as the Chief of Engineers now is, for fitness, only that the choice is not to be restricted to one from a dozen eligible persons, but the whole profession shall be eligible. Next have several grades of executive engineers, who also shall be selected for fitness, nominated by the chief to the President, and approved by the Senate. These to be permanent appointments. Other engineers may be employed as the work may require. Their temporary employment to be by the immediate executive, to whom they will report, with the approval of the Chief. After a term of creditable service these to form a class of accredited engineers, from which, as a rule, promotions to higher grades should be made.

This scheme commends itself to me as fair and just to the existing corps, which would be left as it stands now, but would be relieved of certain classes of duty. To those who would prefer the civil duty opportunity for exchange should be afforded. Those who prefer army position could then devote themselves to military engineering as a special branch of the profession, just as hydraulics and other specialties are followed. The scheme also gives civil engineers all they can reasonably ask for, opportunity to show their fitness, to earn promotion.

Having shown that something better than the existing arrangement is needed, and given in outline my way of obtaining it, I claim also to have shown that there is no clash of interests or classes, no controversy of civil versus military engineers, but rather that the case is that of civil and military engineers joining in an effort to better the public service, render it more efficient in work and more honorable in public estimation, and so elevate the profession of engineer.

In my judgment, it would be a mistake for the outside world to infer from the agitation of this subject that the engineers in government employ are materially worse off than those in the employ of our great corporations and municipalities. Saving in the one matter of no hope for promotion beyond a certain point, they are not. In the matter of pay and treatment they, as a whole, have the advantage. In fact, the position of the engineer working for a monthly stipend, and such form the great body of the profession, is nowhere what it should be, and the government quarter is that in which a first effort at reform has been made, not that it is pre-eminently bad, but that a beginning must be made somewhere. This beginning, it may be hoped, will be followed by general effort to elevate the profession. To this end I note with pleasure the willingness of several societies to unite for a common end by forming the Council of Engineering Societies on National Public Works.

The work of the council, seemingly, has not progressed as was hoped. Possibly the programme laid out was too ambitious for the resources, and needs to be modified. The several societies which are represented in the council, twenty-three in number, with a membership of near 2,700, might well consider whether a more complete organization for other purposes than "to promote an improved system of National Public Works" would not be wise and timely. The object in this case is to exert an influence, and through organization the collective influence of engineers as a body. Would the influence not be more potent in this

particular direction if the organization was more general in its scope. having for its object the elevation of engineering as a profession, and the exercise of the influence of a learned and useful profession upon public opinion and measures?

The need of more intimate relations between existing societies appear in many directions, and the undesirable features of distinct and, in some sense, rival organizations is becoming apparent. Several of the local societies have for several years been associated in the publication of transactions, and have demonstrated their ability to work harmoniously and for joint benefit.

Is there any good reason why all local societies should not join this Association, and then go a step farther, by a partial exchange of the privileges of membership? So that a member of one society removing to the vicinity of another may be transferred, not, perhaps, by right, but by courtesy; not dispensing with the formality of a confirmation of the transfer by a vote of the receiving society, as for a new member, but relieving the transferred member from the payment of initiation or entrance fee in the new relation, and from dues to the old.

Engineer societies have properly been cautious about entertaining propositions looking toward the control of the compensation of engineers in any way, as savoring of trades unionism and unprofessional. As one of the ways to elevate the profession, this cannot be overlooked, nor can the closely related matters, the definition of what constitutes an engineer, and to whom shall that appellation be given, and by what authority conferred. The name and function of lawyer, physician and clergyman may not be assumed at will, or without some preparation, and engineering cannot be said to have taken its place as a learned profession until it is surrounded by some like restriction. As to the matter of compensation, physicians have a minimum scale of prices, which all who wish to be considered reputable practitioners observe. The man of established reputation may charge as much more as he pleases. Lawyers also have a scale of charges proportionate to services rendered, and to the bank account of the client. Architects have their scale, also. With these precedents it cannot be deemed unprofessional for engineers, through organization, to establish a minimum scale of compensation, and certainly we are not barred from claiming our own, as is the clergyman, by the idea that ours is an unworldly profession.

For the want of such a scale for engineering services, monthly wages are paid by corporations which rank below those demanded and obtained by artisans, or even skilled laborers. A young man accepting so low an estimate of the value of his services finds it difficult to respect himself or to command the respect of others. Unqualified persons, judging the position of an engineer by the pay received, and the social rank occupied, see in engineer work an agreeable, if laborious, occupation seemingly open to them, and after a brief apprenticeship with the axe, chain or rod, aspire to the level and transit, and when able to manipulate these they claim to be engineers, write C. E. after their names, and lay for a job.

In connection with public works there is much that this class of persons can do well enough, and there is no objection to their doing it;

but they should not be called engineers. The government service is in advance of general custom here. for in it no one is called assistant engineer who does not perform engineer duties. Transit men, levelers, recorders. rodmen, superintendents, inspectors, overseers, foremen, master workmen, all lie below the plane of the assistant engineer. Outside of the government service, and in ordinary language, a squad of men engaged in a survey is a "corps of engineers." Too often the conduct of such parties leaves along its trail the impression that engineers are worthy candidates for perdition. In Europe, where distinctions of name and title are observed, the fact that one is a civil engineer carries with it the presumption that he is a reputable person to whom social recognition may be safely extended. In America the engineer is regarded as one who may be undeserving of such recognition. This comes from the fact that there is a class of men who disgrace the name of engineer by their depravity and ignorance; who degrade it by accepting the wages of a laborer; who submit to fare and quarters in common with navvies: who associate with the vile and acquire beastly habits of speech and conduct, and with whom, for want of a proper distinction in name, the real engineer is brought into contact, eating and sleeping as well as working with them, until he is judged by the world by the company he is seen in, even if he does not sink intellectually and morally to the level of his associations.

The legitimate office of engineer societies is to elevate its members and the profession generally, and one way in which they may profitably act is closed until a general organization is perfected to which every reputable engineer will be attracted, and which. by careful scrutiny of the character and fitness of applicants for membership, will bar out the unworthy.

The suggestion that societies scrutinize candidates does not imply that there should be a fixed standard of experience or position required for membership. Local associations must be liberal in these respects. My thought looks to character and moral and mental fitness, what the man is capable of being, rather than to the accidents of age and place. A general organization appears to me to be desirable and practicable. It remains to be seen whether the need is recognized to the extent required for action.

WILLIAM RIPLEY NICHOLS,

MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS. DIED JULY 14, 1886.

A Memorial by Prof. George F. Swain.

In the death of Professor Nichols the Boston Society of Civil Engineers, as well as the profession at large, has sustained a loss which is difficult to appreciate, and which only those who knew him personally and professionally, and who were familiar with the charm of his private life, and the high scientific character of his professional work, can fully realize. To do justice to his character and his work in a notice like this is no easy task, but however much the writer may regret that some one better acquainted with the entirety of Professor Nichols' labors was not

selected to write his memorial, he can at least claim to have brought to the task a deep and realizing sense of the gap which has been left in our midst.

William Ripley Nichols was born in Boston on the 30th of April, 1847. After graduating, at the age of 16 years, from the Roxbury Latin School, he spent nearly two years abroad, in company with three companions from the same school, and with his former instructor. During this period, which was largely spent on the continent, he laid the foundation for that proficiency in modern languages which enabled him to read and write German and French almost as faultlessly as he did his native tongue. In fact, his intention at this time was to devote himself to the study of languages, and on his return from abroad he entered Harvard College with the class of 1869. He had attended that institution, however, but a few months, when some trouble with his eyes compelled him to withdraw, and he soon after entered the Massachusetts Institute of Technology, from which he graduated in 1869. His career as a teacher was early begun. Even before graduating he had given instruction in modern languages, and immediately after receiving his degree he was appointed instructor in chemistry, the science to which he had particularly devoted himself during his course. Promotion soon rewarded the earnestness and zeal which he displayed in his work; in 1870 he was made Assistant Professor, and in 1872 Professor of General Chemistry, a chair which he occupied uninterruptedly until his death. But four professors in that institution remain whose connection with the school dates back farther than that of Professor Nichols.

His literary work was begun very early, even before his graduation from the Institute. A paper "On the Chromites of Magnesium," published in 1868, and two in 1869, on the Oxalates of Sodium, Potassium and Ammonium, were extensively copied and quoted in foreign periodicals. He very soon, however, began to devote particular attention to questions of water supply, and to other matters pertaining to the public health; and in 1870 he commenced a series of investigations for the State Board of Health of Massachusetts, which brought him prominently before the public, and soon procured for him a high and enduring reputation as an eminent authority on such subjects. Most of the reports of the Board from this time on contain articles from his pen, often embodying the results of laborious research, and treating of such subjects as the action of Cochituate water on lead pipes, the composition of the ground atmosphere, the filtration of water, the condition of certain rivers and ponds in Massachusetts, the disposal of sewage, the pollution of streams, etc., etc. His report on the Filtration of Potable Water, which originally appeared in the report of the State Board of Health for 1878, was in such extensive demand that it was published separately by Van Nostrand, and met with a wide circulation. In 1879 he contributed the chapter on "Drinking Water and Public Water Supplies" to Buck's "Hygiene and Public Health, and in 1883 he again appeared with a volume on "Water Supply, Considered Mainly from a Chemical and Sanitary Standpoint," a work which at once took its place as a standard authority on the subject. He soon became recognized as one of the leading authorities in this country on the subject of water analysis, to which he devoted special attention, and

his advice and opinion have been sought by many of the large cities and towns in New England, as well as by many in other parts of the country. His activity in this line of investigation was uninterrupted, and at the time of his death his more extended published reports on subjects of this kind numbered about thirty. Notwithstanding this, he found time for literary work in various other directions, as well as for much of a purely chemical character. In 1872, he published an Elementary Manual of Chemistry, abridged from Eliot and Storer's Manual, which was the first book that ever met with marked success for teaching chemistry in the laboratory; and in 1873 he followed with a revision of the Qualitative Analysis of the same authors, which was also favorably received. Still, his labors in his chosen field were so extended and so minute as to leave him no time for many of the other important branches of chemistry; nor did he have any desire to dissipate his energies by attempting to cover too much ground. He paid little or no attention to modern organic chemistry or to manufacturing chemistry, but built his reputation upon his work as a sanitary chemist and a teacher of general chemistry.

Probably the most striking characteristic of Professor Nichols' work lay in his minute and painstaking accuracy. He never jumped at conclusions; he was never satisfied until he was sure that he was right. Chemists who well knew him stated that the painstaking care which he bestowed on his work exceeded anything which they had ever known. He was not a manipulator, and did little of his chemical work with his own hands, but was emphatically a head worker, a man of much executive ability, than whom no one knew better how to plan and carry on a complex investigation. The amount of time and money he spent in simply verifying his results, to satisfy himself of their exactness, was very large. He kept a private assistant constantly employed, more than half of whose time was generally spent in this way. He would take up a new method of water analysis, and keep his assistant on it for weeks, verifying its accuracy on solutions previously prepared. He even sent one of his assistants to England for the express purpose of studying Frankland's method under the direction of that eminent chemist himself. Only a small fraction of his analytical results has been published, but of their absolute accuracy there can never be any question; and his series of investigations for the State Board of Health will always remain classic and models of their kind. His enthusiasm in his work was unbounded, and he lost no opportunity of adding an item of information to his store. He was a member of many scientific societies, whose meetings he always attended when possible, and he made it a point during nearly every long vacation to be present at the gathering of some learned body. Even during the last year of his life, when his strength was slowly but surely ebbing away, his enthusiasm was not checked in the slightest degree. He would cross the ocean, attend the meeting of some learned body, and return to his work with renewed zeal and strength. Even this very year it had been his hope to attend the meeting of the British Association—but his end was nearer than he thought.

Professor Nichols was one of the few sanitary chemists who thoroughly appreciated the close relation between his specialty and the various branches of engineering, and his knowledge of engineering works, details,

and methods was by no means insignificant. Besides associating and affiliating with engineers, he was actively interested in this society, and in the various water-works associations, and he had repeatedly been solicited to join the American Society of Civil Engineers. His industry was remarkable. He was always engaged in some research, and was never satisfied unless he was accomplishing something. Confined as he was a great portion of the day to his work at the school, he was in the habit of doing most of his literary work at night, working till very late and rising early to resume the welcome task. He never neglected an opportunity to visit a locality where anything of interest in his favorite line of study was to be found, and he personally inspected most of the principal water-works and sewerage systems of Europe. He had a large acquintance and correspondence with sanitary chemists and engineers throughout England, Germany and France, and his reputation there was as high as in this country. He was a frequent contributor to the *Sanitary Engineer*, the *Journal of the Franklin Institute*, and other technical periodicals, and he made it a rule to present at least one paper every year before this society. But notwithstanding these multifarious employments, he never seemed in a hurry, and found time for other work to a degree which was astonishing. He was too busy to mix much in society, but was very much interested in church affairs, holding for many years the position of clerk of the Highland Congregational Society and Assistant Superintendent of the Sunday School. He was never absent from the meetings of the trustees, even when so weak that he had to be brought in a carriage, and less than eight months before his death he accepted the responsible post of Superintendent of the Sunday School.

His knowledge of books was enormous. He procured every book, pamphlet or report which appeared in this country or in Europe on sanitary science from a chemical standpoint, and at the time of his death he had accumulated what was probably the finest library in this country on those subjects. He was very methodical, and kept a card catalogue of every work in his possession, numbering about one thousand volumes besides a very large number of pamphlets. He did a great deal of bibliographical work, setting an example which we would like to see more generally followed. His works abound in copious references, and at the end of many of his important reports and papers he added a valuable bibliography of the subject. He also prepared the list of Count Rumford's works published by the American Academy in the complete works of Rumford, and in 1881, while confined to his house by the sickness the result of which five years later carried him away, his active mind would not endure enforced idleness, and he busied himself in compiling a complete catalogue of the works or articles published by graduates or teachers of the Institute of Technology.

As a teacher Professor Nichols will long be remembered by all who came in contact with him as pupils. He always stood ready and willing to aid those who were anxious to learn, and in him the students had before them always a high and inspiring example of the most careful and painstaking accuracy. If to some he appeared at times unnecessarily severe, it was but a consequence and a manifestation of the high standard he

set for himself, and to which it appeared to him that others ought also to conform.

Five years ago, in June, 1881, Professor Nichols contracted a violent cold; but the seeds of disease had been sown before, and this was all that was needed to bring forth their fruit. He had overtaxed his strength in the years gone by—lived beyond his income—drawn on his physical capital. During the winter of 1881 he was confined to his house, reluctantly enough, for until then he had never missed a recitation, either as student or professor. In the spring of 1882 he returned, weak and enfeebled, to take charge of his classes. His cold had developed into pneumonia, which had been followed by pleurisy, and this had finally left him with empyema, from which he never recovered. Yet his spirit was not quenched, and from the time when he was again able to resume his classes he pursued his work with a pluck and determination that was perfectly marvelous, and that can only be termed heroic. Though perfectly well aware of his precarious physical condition, and under circumstances in which most men would have kept their beds, he attended regularly to his classes, and did not, I believe, miss a single exercise until his death. He was always cheerful, sometimes even gay, and his wonted wit and humor sparkled as ever. No one would have suspected from his conversation that he was in anything but the best of health. In the summer of 1884, he was in England, and returned refreshed and apparently better. But he soon grew worse, and in the spring of 1885 he was obliged to leave his home in Roxbury and to take rooms at the Hotel Brunswick, not being strong enough to travel back and forth every day. In the summer a serious operation was performed, apparently with beneficial results; but during the winter of 1885-6 he was so weak that he was obliged every day to travel between the railroad station and his house or the school in a carriage. Still he did not miss a recitation, and during all this time he was laboring as of old, making investigations in his favorite studies and contributing articles to various magazines. No word of complaint escaped him, though he knew his end was not far off, and he worked as before to the limit of his strength.

During 1884–85 he had been busily engaged, conjointly with Professor W. T. Sedgwick, on an investigation for the State Board of Health, concerning the relative poisonous qualities of common illuminating gas and of water gas, and at the time of his death he was engaged in the preparation of an index to the literature of carbonic oxide, and also, with Professor L. M. Norton, in preparing a dictionary of chemical synonyms, thus indulging both his scientific and his bibliographical tastes. Even as late as May 19 of the present year he appeared before this society—his last public appearance—with a paper on the use of galvanized iron and some other service pipes for conveying water. That he fully appreciated his physical condition during all this time is shown by the following words which occur at the close of the preface to his compilation of the publications of teachers and students of the Institute: "This work will be kept in such shape that in case of accident to the present compiler some one else can readily take it up and carry it on." The accident came. In June, 1886, he went abroad to consult eminent medical

authority. Another operation was advised and submitted to, but his strength was too far gone, he could not rally, and on July 14, at Hamburg, Germany, he quietly breathed his last.

He was a member of the following scientific and engineering societies, the mere enumeration of which will show how wide was his reputation: The American Academy of Arts and Sciences; The American Association for the Advancement of Science (of which he was in 1884-85 Vice-President of the Chemical Section); the New York Academy of Sciences; the American Public Health Association; the Boston Society of Natural History; the New England Water-Works Association; the Society of Arts; the Deustche Chemische Gesellschaft; the London Society of Chemical Industry, and the Boston Society of Civil Engineers. After his return from England in 1884, he received from the managers of the International Health Exhibition a certificate of thanks and a bronze medal "for services rendered."

On Professor Nichols' private life it is unnecessary to dwell here, but those who knew him will not soon forget his cheerful, generous, and thoughtful disposition, and his sparkling wit and humor. He was a most enthusiastic friend of the Institute of Technology, to the success of which school he had so largely contributed, by the devotion of a life time. There his memory will long remain green. Those who were associated with him will need no reminder to recall his presence, while his magnificent library, bequeathed to the school, will be his monument for future teachers and scholars, inspiring them to emulate his work, his devotion, and his high example.

SEMI-ANNUAL REPORT OF THE COMMITTEE ON MECHANICAL ENGINEERING.

TO THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

BY JOS. LEON GOBEILLE, CHAIRMAN.

[Read November 28, 1886.]

Mr. President and Gentlemen: In noting recent progress in mechanical engineering, the problem is not what to write, but what not to write. The field so broad; the faculties of man so acute; the age so fraught with wonders of discovery, of invention, and of execution, that the mechanical engineer of to-day stands constantly amid the rush and whirl of events and in the presence of moving things, each one a marvel; in the aggregate, almost beyond the grasp of human intellect.

Perhaps the most important progress in this line during the past year has been in the founding of metals, the manufacture of alloys, and the reduction of refractory ores. The invention in Sweden of "Mitis Metal" and its recent introduction into this country is bound to mark an era in metallurgy. Mitis is simply a wrought-iron, which may be melted and cast precisely as cast-iron now is. It retains all the characteristics of wrought or forged iron, is so fluid that rods no larger than the bristles of an ordinary hairbrush may be cast without difficulty, and so ductile that they may be tied in a knot without fracture. Mitis requires no anneal-

ing, and what the future of this wonderful metal and process will be none can foretell. It is enough to think of, if it be true, that the most intricate, delicate, and ornamental forms may be as cheaply made of wrought iron as of cast. Stoves and light hardware will be especially improved by the adoption of "mitis" in their manufacture. Through the courtesy of Mr. Durfee, President of the American Mitis Casting Co., of New York City, we are enabled to place before you samples of these castings.

The advance in steel manufactures has been phenomenal; among other things, notice the erection all over the country of small Bessemer plants, principally for making nail plate; this made necessary from the fact that during the past year steel nails have largely displaced those made from iron. Notice also that the "New South" has its first Bessemer plant, located at Chattanooga, Tenn., the blowing engines being designed by Ex-President J. F. Holloway of this Club. Also, that the recent action of the Secretary of the Navy in advertising for bids on ordnance and armor plates has caused some activity among the larger forge companies. The heaviest forging for steel guns is to be twelve and one-half tons weight, and must be ready for delivery within two and one half years. The largest piece of forged steel armor plate is to be 6′ × 17′ 6″ × 17″ thick. All must be made in the United States. Also, that the London *Ironmonger* of recent date mentions the phenomenal output of steel at the combined works of the Carnegie Bros., Pittsburgh, for August last, of 21,083 gross tons; it says that the four largest steel works in the world are now in the United States, and predicts the future supremacy of this country in every art of war or peace. Also, that the use of natural gas as a fuel has revolutionized some kinds of manufactures, notably saws and glass. In order to compete in quality and price, al saw manufacturers will be compelled to move their works within the natural gas belt.

Among what might be termed the curiosities of steel manufacture we wish to call attention to the recent paper read before the Iron and Steel Institute, London, by Ferd. Gautier, of Paris, giving details of the process of casting chains of the ordinary type in steel, making a weldless link, and a chain much more uniform and trustworthy than can be made by the old method. The process is not an intricate one, and it is surprising that so obvious an improvement should have been first invented and operated practically in France, instead of in this country.

The method of casting is briefly as follows:

A link previously cast is placed in a vertical position through an iron casting block, which is, of course, in two parts, one lying on the other in a horizontal plane. At one end of this block is the sprue hole which is used as a head to feed the casting, this being made in sand, so that the molten steel may be kept liquid as long as possible. After being poured the mold is instantaneously removed from the newly formed link, thereby leaving it free to contract and avoiding cracks and strains from unequal cooling.

This link when sufficiently cooled is placed in a vertical position, and the operation repeated as before. Like many another invention, the casting of chains in metal, leaving each link free, is no new thing, an

exceedingly difficult form of double link with serrated edges having been cast, one with another, in the form of an endless chain for use as ankle and arm ornaments, by brass artificers in India, certainly as far back as 400 years. We have it on very good authority that a firm in Chicago are now making chains, experimentally, of course, by rolling from a solid square bar of iron without welding a single link, the principle being not unlike the method of casting noted above. The bar is squeezed through a series of four rolls, the length of the chain being limited only by the length of the bar. In this connection we call your attention to a sample of chain in common use, the links of which are solid and put one within the other without welding; also to an endless chain with weldless links of the ordinary type, with molds for casting same, made by a member of your committee. Another curiosity is a cactus barb wire rolled with the barb on.

Mr. Percy, retiring President of the English Iron and Steel Institute, in his presidential address read last September, mentions a new process of making armor and other plate of steel, with an iron centre. This may have been a novelty to him, but not to the average farmer boy of this country, to whom the "soft centre" plowshare and moldboard is an old and mournful story.

Aluminium has come into prominence during the past year by reason of the invention of the Cowles process of electric smelting, with which most of you are familiar. The Cowles Brothers are residents of this city, and have built extensive works at Lockport, N. Y.

Through the kindness of Mr. Thos. D. West, Superintendent of their foundry and a member of this Club, we are able to show samples of what is known as their "rich metal," which is 18 per cent. aluminium and 82 per cent. copper, and of other alloys of this metal. We also call attention to a test bar 12 per cent. aluminium and 88 per cent. copper, which broke at a tensile strain of 126,000 lbs., being about twice the strength of cast steel. If this alloy can be produced at anything like the cost intimated, so as to have it used practically in the arts, it will be a great advance upon any known metal for many purposes. Already the Lockport concern is full of orders for such work as hydraulic cylinders and parts of machines requiring great strength with comparative lightness. The dynamo used at the Lockport works was designed by Mr. Chas. F. Brush, of this city, and built under the supervision of Mr. N. S. Possons, of this Club. It is much the largest dynamo ever built, as well as the best construction known. Its weight is upwards of ten tons, the armature alone weighing 43,000 lbs., and the eight colossal magnets 9,295 lbs. It is driven by a 550 h. p. turbine, and its design and performance have excited the wonder of every one.

Many of you have no doubt read with surprise the claims made in foreign journals of the superiority of the English fire engines over those made in this country. Your committee has been to some trouble investigating this matter, and finds that, as a machine, our fire engines are ahead in nearly every important particular. As a sample of the reckless statements made, we quote from an English paper as follows:

"Competition between English and American Fire Engines.—The Montreal City Council, desirous of increasing its fire-extinguishing plant,

recently invited tenders from all parts of England, Europe, and America, to which eight firms responded. A special committee was appointed to consider the various advantages claimed by each firm for their engine; the committee reported in favor of the Merryweather 'Greenwich,' and the Ahrens engine 'Cincinnati, O.,' as worthy of being tested. Trials of the respective merits of these two engines were made, with the result that the decision unanimously fell to the 'Greenwich.'"

This clipping was sent to the parties most interested, and following is an extract from the letter of the Ahrens Manufacturing Co.:

"We desire to state that the article is not founded on facts, as we did not have an engine in competition with the Merryweather, and did not test an engine for the committee as stated. All that we did do was to simply send a proposition there for what we would furnish an engine, and gave it no more attention, personally or otherwise." This is about the status of all the reports.

Locally in this line has been added by this city a fire-boat, within the period covered by this report, which is something of a novelty and a credit alike to the city and to the engineer who designed it.

In this connection we notice that the old "President" engine at the zinc mines at Friedensville, Pa., has been set at work after a rest of more than seven years. It may not be known to all present that this is the largest engine in the world, being of more than 5,000 H. P., requiring a daily ration of 28 tons of coal to feed its battery of 16boilers, and with each revolution of its ponderous fly-wheel throwing up 17,500 gallons of water.

In pumping engines an attachment brought out by the Worthington Hydraulic Works, Brooklyn, N. Y. (of which Mr. W. M. Barr, a Member of this Club is Superintendent) seems to be of great importance. It is, in brief, a substitute for the fly-wheel, being a conservator of energy. Without going into details, it consists of two small oscillating cylinders attached to an extension of the plunger rod of the engine, preferably beyond the water end. These cylinders and their connecting pipes are filled with water or other liquid. Compressed air from a storage tank is admitted at a suitable pressure to maintain a constant load upon the pistons in the cylinders, through the medium of the interposed water. These pistons act in such a way with respect to the motion of the engine, as to resist its advance at the commencement of the stroke and assist it at the end, the air, meanwhile, exerting its unvarying pressure at each point of the stroke. The two cylinders act in concert, and, being placed directly opposite each other, relieve the crosshead to which they are attached of any sliding frictional resistance, and the engine of any lateral strain. By thus alternately taking up and exerting power through the difference in the angle at which their force is applied with respect to the line or motion of the plunger rod, these two cylinders, in effect, perform the functions of a fly-wheel, but with the important mechanical difference that they utilize the constant pressure of compressed air instead of the energy of momentum.

Speaking of pumping machinery reminds us that Mr. E. D. Leavitt, Jr., consulting engineer of the Calumet & Hecla Mining Co., and also for the firm of Henry R. Worthington, Brooklyn, N. Y., generally acknowledged to be one of the highest authorities on pumping machin-

ery, in his Sibley College lecture of July, 1886, closes with the following summary :

"From what has been said it will be seen that high duty may cost too much. Its value must be predicated on the saving of fuel, as balanced by the interest and depreciation account of the extra expenditure for plant. If the saving tips the scale, high duty is a good investment ; otherwise not." This is a business statement, applicable alike to other kinds of machinery if we change "saving of fuel" to "saving of labor." Mr. Leavitt then goes on to say that "among the most successful examples of high duty pumping engines, commercially considered, that have come under the writer's notice are those of Pawtucket and Providence, R. I., and Lynn, Mass., in all of which instances comparatively small engines, of moderate first cost, are made to do a large amount of work by means of high pressure steam and high piston speed. The key to established success appears to be the adoption of these twin adjuncts of economy." If this is admitted it is but a step to the advocating of high speed stationary engines for general use.

As connected with hydraulics, we note that William Anderson, M. Int. C. E., M. R. I., in a paper read before the Royal Institute of Great Britain, April 9th, called attention to the diminution of cork under pressure, and advocated its use in some places instead of air, in air chambers. Thus, in hydraulic rams, where it is necessary to keep air in the air chamber, to have a steady flow and to prevent the shocks of the water from breaking the machine. We quote from the paper :

"When air is used for this purpose, the air vessel has to be filled, and with most kinds of water the supply has to be kept up while the ram is working, because water under pressure absorbs air. For this purpose a 'sniff valve' is a necessary part of all rams. It is a minute valve, opening inward, placed just below the inner valve ; at each recoil a small bubble of air is drawn in and passed into the air vessel. This sniff valve is a fruitful source of trouble. Its minuteness renders it liable to get stopped up by dirt ; it must of course be submerged, and, if too large, it seriously affects the duty performed by the ram. The use of cork gets rid of all these difficulties ; no sniff valve is needed, the ram will work deeply submerged, and there is no fear of the cork vessel ever getting empty. The duty which even the little ram before you has done is 65 per cent., and larger ones have reached 80 per cent."

Another novel application of cork is for the purpose of storing a portion of the energy of the recoil of cannon for the purpose of expending it in running them out of the port holes after reloading.

A bridge across the Hudson River at Poughkeepsie, N. Y., has something of interest besides the fact that it is an undertaking of great magnitude. It will cost, with its approaches, upward of $10,000,000, but the point to which we call your attention is that the plan contemplates a machine shop and a blacksmith shop erected on the ice in the middle of the river, the best practical way of handling the material and placing it in position nececessitating a great deal of work to be done on the spot, and consequently during the winter season.

At the session of the Institute of Naval Architects in April, Mr. Hal read a paper on Flexible Shafting for Screw Steamers, describing a plan

by which he hopes to reduce the number of breakages or serious accidents to the screw-shafts of ocean going steamers, the importance of which may be inferred when it is taken into account, that it is no uncommon event for some vessels to require a new shaft every one or two years, and in the majority of vessels seven years is considered a good life for the shaft. In very few vessels is the fear of breakage minimized to the extent that the fear of a boiler explosion is. Mr. Hall contended that in many cases there is a want either of accuracy in the line of shafting and its bearings, or of rigidity in the hulls of steamships. The method proposed for remedying these is to use flexible cranks and flexible couplings on the shafts at about two or three places in its length, depending on length of shaft, etc. The details of the scheme has been invented and patented by others. The thrust of the shaft has been taken by ball bearings to reduce the friction, and it is said to work satisfactorily.

During a recent visit to the Morgan Engineering Works, Alliance, O., the great increase in the use of traveling cranes of late was apparent. Thirteen cranes were in process of construction, two being upwards of sixty feet span. Also two shears nearly completed at the same works were designed to cut a plate of cold steel, one and three-fourths inches thick and ten feet wide.

A beautiful example of mechanical engineering is the dome, telescope and apparatus being built for the Lick Observatory by Messrs. Warner & Swasey, of this city, both members of this Club. This apparatus is the largest in the world, and, mechanically considered, nothing so far made even approaches it.

A machine deserving of mention is the box-nailing machine of Lines and Bredman. Its construction (judging from the description and plates) is not complicated enough to render it objectionable, but still too much so to be described here. It is calculated that each machine will perform the work of 8 men, while the work is superior to hand work. It received the highest award at the inventors' exhibition last year.

We have touched upon only a few of the things we ought to notice, your Committee being of the opinion that the report should be as brief as possible, that more time might remain to the individual membership for discussion or for the bringing up matters omitted from this report.

DISCUSSION ON MR. GOBEILLE'S REPORT.

Mr. Gobeille explained that mitis iron stands 10 per cent. less strain than wrought iron, but because it has no fibre it is stronger in the other dimensions. Mitis has all the characteristics of wrought iron and none of steel—you cannot temper it. It is strong and tough.

Mr. A. E. Brown: Is there any place in this country where steel castings can be obtained with practical uniformity of quality? I have struggled for four or five years to find such castings.

Mr. Holloway: I would say, speaking of castings in general, that it is very difficult to make steel casting uniform. One of the greatest difficulties is the shrinkage of the metal. If the casting is intricate, it is very difficult to get it out of the mold before shrinkage shortens it so as to cause fractures. Steel castings have been made, however, very successfully for a great many years. I believe that Mr. Holley, in his travels

abroad, found a place in France where they were enabled to make very sound castings, but I do not know what were the component parts of the metal. The blow-holes of ordinary casting arise from gas inside and not from impurities in the metal. When the casting becomes semi-fluid, the gas forms blow-holes. There is a great difficulty in overcoming the tendency to shorten up and strain itself while in the mold. We have had steel casting made that might weigh a ton at least. Even with casting of that size they are obliged to open the mold as soon as they can. Castings made several years ago, said to be steel castings, were very hard; that was one of the great difficulties. Even with the softer castings now made, it is found desirable to heat and anneal them before working. It is very difficult to overcome the tendency to internal strain in certain parts of the metal. If the casting is put into an annealing furnace and allowed to cool very gradually, it is relieved from its liability to break.

Mr. West: I have had some experience in the casting of strong metals, and I think there will always be a difficulty in overcoming shrinkage. A good deal depends upon the mold. There is a company in Alliance called the Solid Steel Company. They will send out for a time good solid castings, and then for a while there will be blow-holes discovered. A great deal lies with the molder.

Mr. Dunham: Do they take any pains to bring the mold to a high degree of temperature?

Mr. A. E. Brown: In Japan, I believe, in casting iron they heat the mold as well as the metal. This is done, also, in China in casting rice pans, where the casting is not over one-sixteenth of an inch thick. I think it might be applied to steel castings. Has Mr. West had experience in casting ten-per-cent. aluminum bronze?

Mr. West: There is considerable difficulty in obtaining good castings on account of contraction. About the moment of solidification, if the metal finds the least resistance to its contraction, it will tear itself apart.

Mr. A. E. Brown: I understood that ten per cent. aluminum could be treated in the same way as ordinary bronze casting. If it has the same difficulty as the steel in a mechanical point of view, I should think there would be the same difficulty from the engineering stand-point, namely, uncertainty of strain.

Mr. Deering: Is the aluminum which they mix with the copper pure?

Mr. West: Aluminum is obtained from the electrical furnace alloyed with copper. It is put in in the shape of corundum. It contains 48 per cent. of aluminum, 2 of silicon, and 50 per cent. of oxygen. Fifteen pounds of corundum are put into the furnace with
pounds of copper. There is no certainty about the percentage which is obtained.

Mr. Deering: If they could produce pure aluminum would it not make better casting than the form of which you speak?

Mr. West: It would be an advantage if pure aluminum could be delivered to founders, but so far they can only obtain it in alloy.

Mr. Swasey: I understand that pure aluminum retains its lustre in the atmosphere, but does it not corrode rapidly when brought into contact with acids?

Mr. Wood: It dissolves with great ease in hydrochloric acid. Nitric acid has no effect on aluminum. Am not sure about sulphuric. Probably all the chlorides would corrode it rapidly. Aluminum itself is very soft and very weak. It is only valuable when alloyed. It will never enter into engineering enterprises on account of its expense. Aluminum burns at a very high temperature. With regard to the aluminum bronze castings there are two things which enter into the calculation. All alloys of copper have excessive shrinkage or excessive differences at extreme temperatures, but as they melt at a much lower temperature than steel, it would be a nice calculation to determine whether one or the other would have the more shrinkage in casting. It would be difficult to tell which would be greater on account of difference in temperature and difference of expansion and contraction, copper alloys being much affected by heat and steel being difficult to fuse.

Mr. Deering: What is the difference in temperature in the melting point of copper and aluminum?

Mr. Wood: Copper at 1,900, aluminum 1,200, steel 2,500 or 3,000.

Mr. Herman: I have read that the Chinese have a process of preparing copper so that it will take a quantity of steel and can be used as steel, or in place of steel.

Mr. H. C. Thompson: A party in the United States has taken out a patent on that. Among other things journal boxes are being made. I saw one sample where it had made 19,000 miles on a locomotive tender. The party told me that they had brought copper tools to an edge sharp enough to shape different articles as desired.

Mr. A. E. Brown: Aluminum is now said to be a very weak metal. A year ago it was predicted that it would be used for bridges on account of its strength. The Cowles Brothers say that it is equal to good wrought iron. Its specific gravity is two and six-tenths.

Mr. N. B. Wood: Aluminum is really a very weak metal. Anything to the contrary must be a mistake. I cannot give the exact tensile strength.

Mr. West: With reference to aluminum burning, the longer it remains in the crucible the more its strength increases.

Mr. Latimer: Does it not volatilize?

Mr. West: No; there is loss in re-melting metals, probably about 4 per cent. In the case of iron, we find from 8 to 10 per cent. loss.

Mr. Wood: The increase of strength may be due to loss of aluminum by oxidation. In alloys of aluminum 10 per cent. would be perhaps better than 12.

Mr. Holloway: With regard to this question of substituting cork for air in air chambers. There is great difficulty in keeping air in the air chamber in the hydraulic press. Devices are constantly being gotten up to supply the deficiency. If it is true that a substitute like cork can be used under heavy pressure and maintain its elasticity it will be valuable to manufacturers.

Mr. Herman: In regard to the absorption of air by water under pressure water absorbs oxygen. I think the cork used should be granulated cork. In that shape cork would have a great deal of elasticity and retain it.

Mr. A. E. Brown: There is one point that would make cork of value. Cork itself consists of a number of air cells which are water tight. A piece of rough cork consists of an infinite number of air sacs, but I fail to see how it could be used in a granulated form.

Mr. Holloway: If these cells are packed so that the fluids cannot get to them of course they are constant reservoirs of air. I suppose that under pressure the cells might be broken and filled up.

Mr. Brown: Prof. Michelson says that cork is compressible to one-twentieth of its original volume, if so it must be almost air.

Mr. Barber: I think that the cells in the cork, while under pressure, are acted upon in such a manner by the pressure that it would be impossible to rupture them. That pressure is uniform is illustrated by placing a rubber bag in a quantity of water; the bag, although made of soft rubber, will compress uniformly. I suppose each cell in the cork will act in the same way. There is an article on this subject in the October number of Van Nostrand's monthly.

Mr. Holloway: We have a very modest Member here (not the gentleman speaking), to whose work I should like to call attention. It is known to some of us that Mr. Swasey has contrived a very ingenious gear cutting machine. I only saw it in process of construction. We all know that in gear cutting machinery there has been a vast amount of knowledge expended. I believe that Mr. Swasey has struck upon a new and unknown method.

Mr. A. E. Brown: I would like to add that I have seen the machine working, and have heard it spoken of as one of the most wonderful of its kind. I saw the cutter revolving in the gear that had been finished. A piece of paper was held under it, and there was not a particle of dust upon the paper, which proved that it did its work perfectly.

Mr. Swasey: I tried to take advantage of one of the oldest principles of gearing on the interchange system. I simply tried to turn what is called the Lang system around. I reasoned, if all gears will run into a rack, then with a revolving rack or cutter I can cut all gears. It became then a mechanical problem to make a revolving rack. I will not now say more in regard to the machine, but hope to have the pleasure of explaining it more in detail at some future meeting.

Mr. Wood: I have also seen the machine working, and it was a marvel to me to find a machine that could cut any kind of gear from a 200-tooth gear down to 11-tooth, with the same cutter.

Mr. Latimer: I would like to call your attention to Mr. Brown's machine for handling ore. It is not one of the present year, but there has been work done upon it recently to make it somewhat new. I do not think there is anywhere superior machinery for this purpose.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

ASSOCIATION OF ENGINEERING SOCIETIES.

ANNUAL REPORT OF THE CHAIRMAN OF THE BOARD.

To the Association of Engineering Societies:

The fifth annual statement of the Board of Managers of the Association, which is hereby respectfully presented, shows no radical changes in the affairs of the Association since the last annual report.

The membership of the Associated Societies has continued to increase in a greater ratio than heretofore. When it is remembered that no accessions have come from the outside, but that the increase is due wholly to the growth of the several Societies, the rate of increase becomes peculiarly noticeable.

The total membership of the Societies belonging to the Association as shown by the mailing list, Nov. 1., the close of each fiscal year, is as follows:

1882	405	1885	572
1883	460	1886	656
1884	524		

Two Societies, viz., the Boston Society of Civil Engineers and the Western Society of Engineers, have a membership of 174 each, and are, under the Articles of Association, each entitled to two representatives in the Board of Managers.

In accordance therewith the former Society has appointed Prof. Winfield S. Chapin as their second representative.

The Western Society has not yet availed itself of this privilege, but it is to be expected that it will, early in 1887. Aside from the case above noted, there has been no change in the personnel of the Board, which now stands as follows, viz.:

Horace L. Eaton and Prof. Winfield S. Chaplin, for the Boston Society of Civil Engineers; Prof. J. B. Johnson, for the Engineers' Club of St. Louis; M. E. Rawson, for the Civil Engineers' Club of Cleveland; Geo. W. Cooley, for the Engineers' Club of Minnesota; C. J. A. Morris, for the Civil Engineers' Society of St. Paul; Benezette Williams, for the Western Society of Engineers, and H. G. Prout, Secretary.

The publication of the Index has been continued during the past year, and, as at the end of the previous year, will be rearranged alphabetically, with additions and cross references, and published in a separate form, suitable for binding with the JOURNAL.

The increase in the receipts from sales and subscriptions to the JOURNAL, as shown by the Fourth Annual Report, has remained about the same for the past year, showing that the Index is still exerting the effect then noted.

No meeting of the Board has been held during the year, but owing to the increase in the number of Managers and other possible changes, a meeting should be held early in 1887 to consider Association affairs and to re-organize the Board.

The expenditures of the Association for Vol. V. are as follows :

Composition, press work, paper, binding and mailing	$1,526.46
Engraving	321.25
Expenses	573.84
Postage	64.04
Deficit, Vol. IV	32.45
	$2,518.04

Receipts as follows :

Boston Society of Civil Engineers		$480.25	
Western Society of Engineers		370.00	
Engineers' Club of St. Louis		379.00	
Civil Engineers' Club of Cleveland		399.00	
Engineers' Society of Minneapolis		116.75	
Civil Fngineers' Society of St. Paul		62.00	
		$1,807.00	
Sales	$116.72		
Subscriptions	202.12		
Advertising	311.68		
		630.52	
			$2,437.52
Leaving a deficit of			$80.52

This deficit being slightly larger than the one appearing at the end of last year, and there having been assessments to the amount of $3 per copy of the JOURNAL taken by the Societies collected during the year, it is seen that the cost of the JOURNAL has been a few cents more than $3.

Since the organization of the Association the assessments have averaged $3 per annum per copy taken by the several Societies. In addition to this, an entrance fee of 50 cents per member was paid by each Society.

Besides $127 due from advertisements, the Association has, as assets, back numbers of the JOURNAL, which will be sold from year to year.

Respectfully submitted, BENEZETTE WILLIAMS, Chairman.

CHICAGO, December 30, 1886.

BOSTON SOCIETY OF CIVIL ENGINEERS.

JANUARY 19, 1887 :—A regular meeting of the Boston Society of Civil Engineers was held and called to order at 7:45 P. M., Vice-President L. Fred. Rice in the chair, twenty-two Members, two visitors present.

The record of the last meeting was read and approved.

Messrs. W. R. Billings, W. S. Brown, G. W. Hamilton, C. A. Pearson, J. Sondericker were elected Members of this Society.

Messrs. E. H. Lincoln, Charles Mills, James E. Stone were proposed for membership, recommended by F. L. Fuller, F. W. Hodgdon, E. W. Bowditch, G. M. Tompson, C. Harris, G. W. Blodgett.

On motion of the Librarian, it was voted : That the sum of thirty dollars, or so much thereof as is necessary, be appropriated for binding the periodicals of the Society for the year 1886, and for other purposes in the Library.

Mr. E. C. Clarke presented the subject of "Emergency Lectures." These lectures are designed to explain the proper means to be employed in caring for men injured by accident or otherwise, and are given by a qualified surgeon, who explains his methods by applying them to a boy, and further illustrates by the use of a skeleton. It was the opinion of the members present that such a course of lectures would be of interest and of undoubted service. On motion it was voted: That the subject of emergency lectures be referred to the Government, with instructions to take the necessary steps to organize such a course.

Mr. George W. Blodgett read a paper on the Steam Engine in Electric Lighting.

Mr. L. Fred. Rice described some problems in construction met with in prac-

tice, exhibited drawings of several roofs of curious design, and explained the construction of the Green River bridge, Troy & Greenfield Railroad.

[*Adjourned.*] H. L. EATON, Secretary.

REPORT SUBMITTED DECEMBER 15, 1886.

Your Committee appointed to consider the communication of the American Society of Civil Engineers, of Sept. 1, 1886, would respectfully recommend the adoption of the following resolutions, as expressing the opinion of this Society:

That such an arrangement as will lead to the joint publication of the papers of the engineering societies of the United States is very desirable.

That a closer union of the American Society and the local societies would be for the benefit of the engineering profession.

That this Society would be glad to consider any proposition from the American Society looking towards the accomplishment of these ends.

Respectfully submitted,
F. P. STEARNS,
W. S. CHAPLIN,
J. E. CHENEY,
WM. E. McCLINTOCK.

On motion, it was voted, That the report of this Committee be accepted and adopted, and a copy be sent to the American Society of Civil Engineers.

ENGINEERS' CLUB OF ST. LOUIS.

SPECIAL MEETING.

DECEMBER 21, 1886:—A special meeting of the Club was called by the President to take action in regard to the death of Col. C. Shaler Smith. The meeting was called to order at 4:45 P. M., at Mercantile Library, President Potter in the chair, and twenty-three members present.

The Chair stated his reasons for calling the Club together, announcing the death of Col. C. Shaler Smith, and calling attention to his valuable services to the Club and his high standing in the profession. He suggested some action on the part of the Club appropriate to the occasion.

On motion, the Club decided that the Chair appoint a committee of three to draft suitable resolutions to be presented at the next meeting of the Club. Messrs. R. E. McMath, E. D. Meier and J. B. Johnson were appointed such committee.

The Chair called upon members of the Club for remarks. Col. E. D. Meier spoke of the lovable character of the deceased, and the pleasure of intercourse with him, both in business and socially. His versatility of talent and his familiarity with all the branches of engineering were remarkable. His original experiments and research were of great value to the profession. Col. Smith would be best remembered in St. Louis by his connection with the St. Louis bridge and the St. Louis Exposition, the success of the machinery department being due to him. Col. Meier related the accident which resulted in his death. Col. H. C. Moore spoke briefly of the standing of the deceased in the profession.

H. P. Taussig, formerly an assistant to Col. Smith, spoke briefly of his intercourse with him. Prof. Potter mentioned a letter dictated by Col. Smith very recently, which was full of cheerfulness. Professor Johnson spoke of the wonderful amount of work carried on by Col. Smith. The training received by the young engineers in his employ would perpetuate his influence on the profession.

On motion, it was decided that the Club attend the funeral, and the Secretary was directed to tender the family the services of pall-bearers, if no other arrangements had been made.

It was suggested that a committee on memoir be appointed at the next regular meeting. The matter of a floral tribute was left in the hands of the Committee on Resolutions.

It was directed that the Club meet at 2828 Washington avenue, a half hour before the hour announced for the funeral services.

[*Adjourned.*] WM. H. BRYAN, Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. VI. FEBRUARY—APRIL, 1887. No. 4.

This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

FORMULAS FOR BEARING POWER OF PILES.

IRA O. BAKER, MEMBER OF THE WESTERN SOCIETY OF CIVIL ENGINEERS.

[Read February 1, 1887.]

§ 1. Although this is not by any means the most important question which the engineer meets, it is of enough practical importance to warrant a better treatment than the writer has seen. The state of knowledge of this question is hardly creditable to the profession. There is no lack of formulas, but no one need be astonished to find that any two taken at random will give very different results. If the formulas for which there seems to be good authority be applied to any particular case there will be an astonishing divergence in the results ; the writer remembers an article on this subject which quotes four formulas, of which the largest result was 1,771 times the smallest. The practicing engineer has neither the time nor patience to search through the tailings of the numerous mathematical threshing machines to see if there are any grains of wheat ; he either rejects the whole mass and trusts to his own experience and judgment, or takes an average of all the formulas he can find and feels that he is in accord with the combined wisdom of the profession. The self-reliant man chooses the former, the timid trusts to the latter. This is no picture of the fancy ; both cases frequently occur. Neither is creditable nor scientific. The writer asks your attention a few moments to an examination of this question to see if the limits of the unknown and uncertain cannot be contracted a little.

§ 2. Two cases must be distinguished, that of columnar piles or those whose lower end rests upon a hard stratum, and that of ordinary bearing piles in which the supporting power is due to the friction of the earth on the sides of the pile. In the first case, the bearing power is limited by the strength of the pile considered as a column, and, since the earth prevents lateral deflection, at least to a considerable degree, the strength of the pile will approximate closely to the crushing strength of the material. This case needs no consideration here.

There are two methods which have been used to determine the supporting power of a pile driven by the impact of a hammer. One consists in computing the power required to force the pile into the ground, from the relation of length and size of pile, weight and velocity of the ram, and

the distance the pile moved at the last blow. The second method consists in determining the supporting power by applying a direct pressure or load to the head of the pile. Each of these methods may be sub-divided into two others.

The formula for bearing power in terms of weight and length of pile, weight and velocity of hammer, etc., may be determined from a consideration of the theoretical conditions involved, or a relationship may be determined by experiment. We will call the formula deduced by the first method a *rational formula for supporting power*, and that by the second an *empirical formula for supporting power*.

§ 3. *Rational Formula.*—When the ram strikes the head of the pile, the first effect is to compress both the head of the pile and the ram; the more the ram and pile are compressed the more the force required, until finally the force of compression is sufficient to force the pile through the soil. The amount of the pressure on the head of the pile, when it begins to move, is what we wish to determine.

To produce a formula for the pressure exerted upon the pile, by the impact of a descending weight, let

W = the weight of the ram.
w = " " " pile.
S = " section " ram.
s = " " " pile.
L = " length " ram.
l = " " " pile.
E = the co-efficient of elasticity of the ram.
e = " " " pile.
v = the velocity with which the ram strikes the pile.
h = the height of fall necessary to attain the velocity v; $h = \dfrac{v^2}{2g}$
d = the penetration of the pile, *i. e.*, the distance the lower end of the pile is moved by the last blow.
P = the pressure which is just able to move the pile the very small distance d, *i. e.*, the pressure produced by the last blow; or, briefly, P may be called the supporting power. If distances are taken in feet and weights in pounds, the resulting value of P will give the sustaining power in pounds per square foot of head of pile, and similarly for other dimensions.

Then Wh is the accumulated energy of the ram at the instant it strikes the head of the pile. This energy is used up (1) in compressing the ram, (2) in compressing the head of the pile, and (3) in moving the pile as a whole against the resistance of the soil.

In the early stage of the contact between ram and the pile, part of the energy of the ram is being used up in overcoming the inertia of the pile; but in the last stage of the compression, this energy is given out by the stoppage of the pile. At most, the effect of the inertia of the pile is small; and hence, the effect of the inertia and weight of the pile will be neglected.

(1). The energy consumed in compressing the hammer is represented by the product of the compression or shortening of the ram and the mean pressure. From the principles of the resistance of materials, the

shortening or compression, for a pressure P, is $\frac{P\,L}{S\,E}$ *provided* the pressure P is uniform throughout. In the case of a striking weight, the pressure, which is due to inertia, varies as the material, or the pressure at any point in the ram varies as its distance from the face; and hence the mean pressure on the ram is $\frac{1}{2}\,P$. Consequently the shortening is $\frac{1}{2}\,\frac{P\,L}{S\,E}$.

If the fibres of the face of the ram are not seriously crushed, the mean pressure will be one-half of the maximum pressure due to impact ; or the mean pressure during the time the ram and pile are being compressed is $\frac{1}{2}\,P$. Then the energy consumed is $\frac{1}{4}\,\frac{P^2\,L}{S\,E}$.

(2). The mean pressure on the head of the pile is $\frac{1}{2}\,P$ as above. For simplicity assume that the pile is of uniform section throughout. To determine the shortening, notice that for the part of the pile above the ground the maximum pressure is uniform throughout, but that for the part under the surface the maximum pressure varies as some function of the length. Weisbach makes no distinction between the two parts of the pile, and evidently assumes* that the pressure is uniform throughout. Rankine makes no distinction between the two parts, and assumes† the pressure to vary directly as the length. Neglecting to distinguish between the two parts of the pile is equivalent to assuming that the whole pile is in the ground. With a pile wholly immersed the maximum pressure will be uniform throughout only when the whole resistance to penetration is at the point. Such a condition will never be realized in practice. Hence the assumption, Weisbach's, that the shortening is uniform throughout and equal to $\frac{P\,l}{s\,e}$ is not the proper one. For a pile wholly immersed the assumption, Rankine's, that the pressure varies as the length, and that hence the shortening is $\frac{1}{2}\,\frac{P\,l}{s\,e}$ is at least very nearly true. But, remembering that the resistance is generally greater at the lower end than at the upper, and that any swaying or vibration of the upper end will still further diminish the resistance near the top, possibly some value intermediate between the two preceding ones would more nearly represent the actual conditions of ordinary work. We will assume that the mean pressure on the fibres of the pile is two-thirds of that on the head, which is equivalent to assuming that the shortening is $\frac{2}{3}\,\frac{P\,l}{s\,e}$, when the pile is wholly immersed. If only a part of the pile is in contact with the soil the shortening will be $\frac{P\,l'}{s\,e} + \frac{2}{3}\,\frac{P\,l_1}{s\,e} = \frac{P}{s\,e}\,(l' + \frac{2}{3}\,l_1)$ in which l' is the exposed portion and l_1 the part immersed. For simplicity in the following discussion the shortening of the pile will be taken at $\frac{2}{3}\,\frac{P\,l}{s\,e}$. If a formula is desired for the case when the top pro-

* Mechanics of Engineering, 4th ed. (Coxe's Translation), p. 699.

† Civil Engineering, p. 602.

jects above the ground, it will only be necessary to substitute $(\frac{3}{2} l' + l_1)$ for l in the three following equations :

Under the first assumption, the energy lost in the compression of the pile is $\frac{1}{2} \frac{P^2 l}{s e}$; under the second it is $\frac{1}{4} \frac{P^2 l}{s e}$, and for the intermediate value, as above, it is $\frac{1}{3} \frac{P^2 l}{s e}$. The last will be used in the following discussion.

(3). The energy represented by the penetration of the pile is $P d$.

§ 4. Gathering these results together we have

$$Wh = \frac{1}{4} \frac{P^2 l}{S E} + \frac{1}{3} \frac{P^2 l}{s e} + P d. \qquad (1)$$

From which

$$P = \sqrt{Wh \frac{12 S E s e}{3 L s e + 4 l S E} + \frac{36 d^2 S^2 E^2 s^2 e^2}{(3 L s e + 4 l S E)^2}} - \frac{6 d S E s e}{3 L s e + 4 l S E} \qquad (2)$$

Putting $\frac{6 S E s e}{3 L s e + 4 l S E} = q$, and (2) becomes

$$P = \sqrt{2 q Wh + q^2 d^2} - q d. \qquad (3)$$

Equation (3) is the same as Weisbach's, except in form and for the reason stated in paragraph (2) of the preceding article.

Weisbach's formula can be obtained by writing $\frac{1}{2}$ instead of the $\frac{1}{4}$ and $\frac{1}{3}$ in (1), and solving ; it is*

$$P = \left(\frac{H H_1}{H + H_1}\right) \left(\sqrt{2 \left(\frac{H + H_1}{H H_1}\right) h W + d^2} - d\right), \qquad (4)$$

in which $H = \frac{S E}{L}$, and $H_1 = \frac{s e}{l}$.

Rankine's formula can be obtained from (1) by neglecting the term expressing the energy consumed in the compression of the ram, and writing $\frac{1}{4} \frac{P^2 l}{s e}$ instead of $\frac{1}{3} \frac{P^2 l}{s e}$, *i. e.*, assume the compression of the pile to vary with the depth, and then solving ; it is †

$$P = \sqrt{\frac{4 W h s e}{l} + \frac{4 d^2 s^2 e^2}{l^2}} - \frac{2 d s e}{l}. \qquad (5)$$

§ 5. An examination of equation (2) shows that the pressure upon the pile varies with the height of fall, the weight, section, length and co-efficient of elasticity of both ram and pile, and with the penetration. It is easy enough to see that the weight of the ram and the height of the fall should be included. The penetration is the only element which varies with the nature of the soil, and so of course it should be included. If any one will try to drive a large nail into hard wood with a piece of leather or rubber intervening between the hammer and the head of the nail, he will be impressed with the fact that the yielding of the leather or rubber appreciably diminishes the effectiveness of the blow ; essentially the same thing occurs in trying to drive a large nail with a small hammer, except that in this case it is the yielding of the material of the hammer which diminishes the effect of

*Mechanics of Engineering, p. 701.

† Civil Engineering, p. 604.

the blow. In driving piles the material of the pile and ram act as the rubber in the first illustration, and, reasoning by analogy, those elements which determine the yielding of the material of the pile and ram should be included in the formula. Obviously the pressure due to impact will be greater the harder the material of the pile. Consequently the length, section and co-efficient of elasticity of the material of the pile and ram should be included. The yielding of the material of the ram is probably small, and might possibly be omitted, but as it adds no complication, as will appear presently, it is included. Notice that Weisbach's and Rankine's formulas omit it. Notice that if the head of the pile is bruised or "broomed," the yielding will be increased, and consequently the pressure due to the blow will be decreased.

In this connection the following table, given by Don. J. Whittemore in the Transactions of the American Society of Civil Engineers, Vol. XII., page 442, to show the gain in efficiency of the driving power by cutting off the bruised or broomed head of the pile, is very instructive. The pile was of green Norway pine; the ram was of the Nasmyth type, and weighed 2,800 pounds; the face was 36 inches. The numbers in the first column are the successive feet of penetration; in the second the number of blows required to drive the pile the corresponding foot.

3	5	Head adzed off.	
4	15	15	275
5	20	16	572
6	29	17	832
7	35	18	825*
8	46	Head adzed off.	
9	61	19	213
10	73	20	275
11	109	21	371
12	153	22	378*
13	257		
14	684	Total No. of blows	5228

A similar pile driven near the former under similar conditions required 9,923 blows.

Notice that the average penetration per blow was $2\frac{1}{2}$ times greater during the 15th foot than during the 14th; and nearly 4 times greater in the 19th than in the 18th. It does not seem unreasonable to believe that the first blows after adzing the head off were correspondingly more effective than the later ones; consequently it is probable that the first blows for the 15th foot of penetration were more than 5 times as efficient as the last ones for the 14th foot, and that the first blows for the 19th foot were 8 or 10 times more efficient than the last ones for the 18th foot. This shows how unscientific it is to prescribe a limit for the penetration without specifying the accompaning condition of the head of the pile, and also that a volley of two or three blows (the penetration per blow can be obtained more accurately by taking the mean for two or three than by a single blow) is better than more.

Also since the co-efficient of elasticity of sound material is included in the formula, the head of the test pile should be sawed off so as to present a solid surface for the last or test blow of the ram.

The formula is approximate, since the assumptions made in deducing it

* Possibly a typographical error; possibly evidence that the surface had begun to consolidate.

may not be strictly realized in practice. It is also approximate because of the neglect of the retarding effect of the friction of the falling weight against the air and the vertical guides. These two elements diminish the effect of the blow, but the amount cannot be computed. The smaller the fall the more nearly will the formula give the true supporting power, for then the loss due to friction against the guides and air is least.

For the cases as they occur in common practice, q in (3) is about 6,000, when the other data are given in feet and tons.

Although a formula derived in this way, involving so many assumptions the effect of a small error in which cannot readily be seen, and depending upon so many variables, the values of which cannot easily be found, cannot be relied upon implicitly, it is valuable as showing the law of variation of the pressure and also as showing the conditions which should be fulfilled by an empirical formula.

If it is thought not desirable to trust entirely to theory, then the formula

$$P = \sqrt{2\, q\, W\, h + q^2\, d^2} - q\, d \qquad (6)$$

may be considered as giving only the form which the empirical formula should have; under this condition q becomes a numerical co-efficient to be determined by experiment. The experiment must be made by driving a pile and measuring d, after which the sustaining power of the pile must be determined by applying a direct pressure. Of course, the last blow must fall on sound material. The observed values of P and d are to be inserted, and the value of q found by solving the equation. Each experiment will give a value of q, and since q varies with the section, length and co-efficient of elasticity of ram and pile, the experiments should include all values of the variables that are likely to occur in practice, and those occurring most frequently should predominate in the experiments. The mean value of q should be used in the final formula.

The writer has been unable, even though he has spent considerable time in the search, to find any record of experiments by which he might determine the value of q; generally some important factor is lacking. The only experiments, even roughly approximating the right conditions, are the two recorded in Trautwine's Pocket Book, Ed. 1885, pp. 643–4. These are unsuitable for this purpose, since we know certainly that for one of them (the second) the last blow was not struck on sound wood, and as it is highly probable that for the other it was not. The first example (after reducing to a 2,000-lb. ton) makes $q = 1.5$; assuming, as seems reasonable in the light of the above table, that if the last blow had been delivered on sound wood, the penetration would have been nearly three times as much, will give $q = 6{,}000$. The second example as recorded makes $q = 335$. In this case we know* that the pile had received 59 blows of a light hammer, with a fall increasing gradually from 6 to 35 feet, without the head having been cut off, and that hence the last blow was not struck on sound wood; assuming that if the last blow had been struck on sound wood the penetration would have been doubled, will give $q = 6{,}000$.

When the pile is driven to absolute refusal, $d = 0$, and the formula

* Circular of the Office of Ch. of Engs., U. S. A., Nov. 12, 1881, Pile Foundations and Pile Driving Formulæ, page 3, table of penetrations.

becomes simply, but accurately, $P = \sqrt{q\,W h,}$ which shows a slightly different way of determining q.

To deduce an empirical formula of a little greater accuracy than as above, notice that the q in the second and third terms of the right-hand member of (6) depends upon the form of ram and pile only, while the value of q in the term $2\,q\,W\,h$, if determined by experiment, will also depend upon the amount of energy lost by the friction of the ram on the guides and against the air. We may then write the formula

$$P = \sqrt{2\,q'\,w\,h + q^2\,d^2} - q\,d, \tag{8}$$

in which q' and q are numerical co-efficients to be determined by experiment. Each experiment will give an equation of condition ; and the only correct way of determining q' and q from these equations is by the method of least squares. Many empirical formulas are in error owing to a failure in this respect.

§ 6. EMPIRICAL FORMULAS.—The reader should constantly bear in mind that any empirical formula is only a condensed table of values, and that generally it gives only a mean of such values. The law which it is desired to express in an empirical formula may be of such a nature that a mean value is of little or no use. For example, suppose it were desired to find an empirical formula for the value of the tangent of an angle ; we might find the tangent for, say, 1°, 11°, 21°, 31° and 41°, and divide the sum of the tangents by the sum of the angles ; the quotient (0.2) is the mean value of the tangent of 1°. The empirical formula would then become *the tangent of an angle is equal to* 0.2 *times the number of degrees.* Obviously such a formula is inapplicable to angles near 90°, and it is rudely approximate for angles within the limits from which it was derived. It is evident that this empirical formula is of the wrong form.

Even if the formula is of the correct form, it is equally essential that the value of the constants therein should be correctly determined. For example : suppose that it were desired to determine the equation of the straight line $A\,B$, Fig. 1. Since the given line is straight, we will assume that the empirical formula is to be of the form $y = m\,x$. We might find m by measuring the ordinates 1, 2, 3, and place m equal to their mean. If 1, 2, 3, be the numerical values of the respective ordinates, the formula becomes $y = 2\,x$, which gives the line $O\,C$, the mean ordinate to $O\,C$ is equal to the mean ordinate to $A\,B$, but the two are not by any means the same line.

For another illustration assume that some law is correctly represented by the curve $A\,B$, Fig. 2. The form of the empirical formula may be such as to give the curve $C\,D$. These curves coincide exactly at two points, and the mean ordinate to the two curves is the same. To use a common expression, we may say that, "on the average, the empirical formula agrees exactly with the facts;" but it lies, nevertheless.

Even if of the correct form and correctly deduced, an empirical formula can be safely applied only within the limits of those values from which it was determined. For example, a law may be represented by the curve $A\,F\,B$, Fig. 3 ; from observations made in the region $A\,F$, the empirical law has been determined, which gives the curve $C\,E\,D$. To use an empirical formula intelligently, it is absolutely necessary that the limits of the values from which it was derived be known.

Of course, the observations from which the empirical formula was deduced cannot properly be used to test the correctness of the formula; such a procedure can only check the mathematical work of deriving the constants.

Elementary as the preceding principles are, many empirical formulas are worthless, owing to a disregard of these conditions in deducing them. The discovery of a law and the expression of it in mathematical formula requires talent of no low order, and the skill required increases very rapidly with the complication of the law.

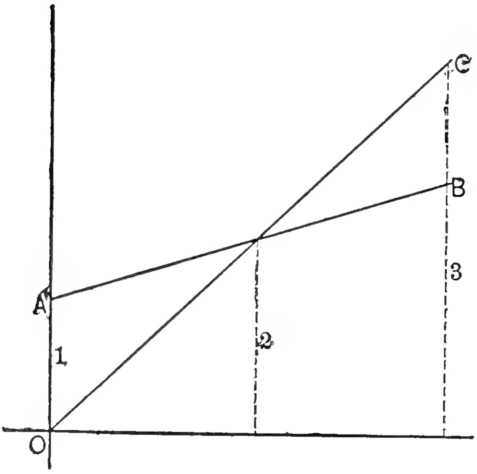


Fig. 1.

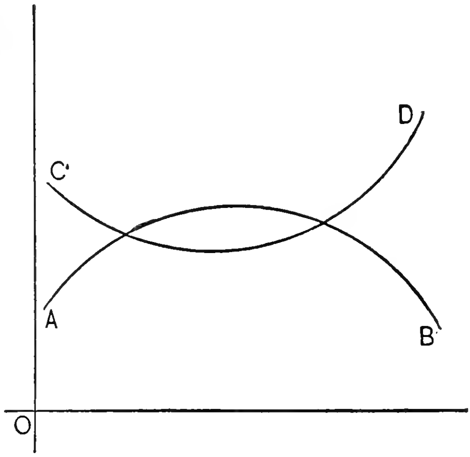


Fig. 2.

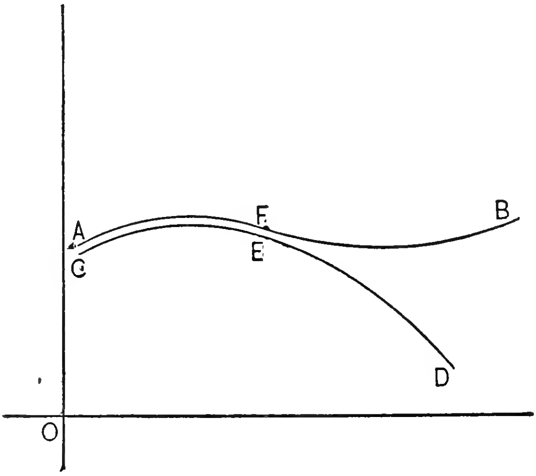


Fig. 3.

§ 7. We will now consider some of the empirical formulas which have been proposed for the supporting power of piles. It will not be necessary to consider all that have been proposed; some are manifestly too absurd for a moment's thought. We will discuss only those that are frequently quoted. It will not be necessary to consider formulas for the supporting power of piles used as columns.

*Haswell's formula** for the dynamical effect of a falling body is $P = 4.426\ W\ V$, "as deduced from experiments." Notice that the

* Pocket-Book, p. 419.

formula neglects entirely the yielding of both bodies. A formula similar to this can be obtained* by letting a weight fall, and measuring the resulting pressure by a coiled spring; if only one weight and a single spring are used, the pressure will vary as the velocity; but if different falling weights and springs of different stiffness are used, it will be impossible to express the results in a formula of the above form. This formula is probably correct within the limits and under the conditions for which it was deduced, but these limits and conditions are immensely different* from those of common pile driving.

Beaufoy is often credited with the formula $P = 0.5003\ W\ V^2$, "as determined by experiment." Notice that it involves and neglects the same elements as the preceding, but makes the pressure vary as the square of the velocity. A formula similar in form to the above can be deduced by using the same falling weight and springs of such relative stiffness as will stop the weight in the same distance.† It is worth noticing that if the experiments are made with different weights and the same spring the formula becomes† $P = c\ v\ \sqrt{W}$, in which c is some constant.

This and the preceding formula were without doubt deduced from experiments made by letting weights of a few ounces fall a few inches and strike against a small spiral spring. The magnitude of the experiments was such as to invalidate the constants, and the manner of making the experiments invalidates the forms of the equations. They would give the same bearing power for all coils, other things being the same. Farther comment is unnecessary.

Major Sanders' formula is often used by U. S. Army engineers and frequently quoted by others ; it is $P' = \frac{W h}{8 d}$, in which P' is the safe bearing power, which is some fractional part of the ultimate supporting power. The original article‡ is not at hand, and it is not known how it was deduced ; but it looks very much as though the formula assumed that the energy of the falling weight was wholly employed in forcing the pile into the ground—*i. e.*, that $P d = W h$, or $P = \frac{W h}{d}$, and took the safe working load taken as one-eighth of the ultimate supporting power—*i. e.*, $P' = \frac{1}{8} P = \frac{W h}{8 d}$. The falsity of such an assumption is apparent. If this formula were applied to the case of an elastic pile driven in soft soil by a light hammer with a long fall (remember that the greater the velocity the greater the loss of energy due to impact), it will give nearly or quite infinity for the bearing power, when probably a steady pressure only a few times greater than the weight of the hammer would force the pile into the ground. Although it is always referred to as being " deduced from experiments," it is difficult to believe that such is the case ; it looks very much like a crudely approximate theoretical formula.

Colonel Mason's formula is $P = \frac{W^2 h}{(W + w d)}$, in which w is the weight

* *Van Nostrand's Magazine*, Vol. 17, pp. 325.
† *Ibid.*
‡ *Jour. Frank. Inst.*, 3d series, Vol. XXII.

of the pile. This is the same as one of Weisbach's approximate formulas,* which he states is applicable only when the pile drives very easily; it assumes that the whole energy of the falling weight is used in overcoming the resistance to penetration. As in the preceding case, this is frequently referred to as a "practical formula," but an examination of the original memoir † shows that it is wholly a theoretical formula, with no pretensions of being anything else. The formula is sometimes referred to as having been "tested by a series of experiments;" apparently the only basis for this is that the piles upon which Fort Montgomery (Rouse's Point, N. Y.) stood from 1846 to 1850 without any sign of failure, when tested by this formula showed a co-efficient of safety of $3\frac{6}{10}$. The evidence is not conclusive; first, the factor is large enough to cover a considerable error in the formula; second, since the formula assumes that all of the energy in the descending ram is used up in overcoming the resistance to penetration, the computed bearing power is too small, and consequently the co-efficient of safety is even greater than as stated; and third it is probably safe to say that after a pile has stood a short time its bearing power is greater than at the moment the driving ceased, owing to the settlement of the earth about it.

Nystrom's formula‡ is $P = \frac{W^3}{(W+w)^2}\frac{h}{d}$, in which w is the weight of the ram. Notice the similarity in form between this and the preceding one; since it involves the same terms, it should have the same form. In a later book§ Nystrom gives the form $P = \frac{3}{4}\frac{Wh}{d}$, the assumption being that "*about* 25 *per cent. of the energy of the ram is lost by the crushing of the head of the pile*" (italics by the writer of this article). Both of these formulas are roughly approximate rational formulas, although often cited as "practical formulas."

McAlpine's formula is‖ $P = 80\ (W \text{ tons} + 0.228\ \sqrt{h \text{ ft.}} - 1)$. It was deduced from experiments made in connection with the construction of the Brooklyn dry-dock. "The piles were chiefly of spruce timber from 25 to 40 feet long, averaging 32 feet driven length. They were from 12 to 18 inches diameter at the head, and never less than 7 inches at the foot. The soil was silicious sand with comminuted particles of mica and a little vegetable loam and generally encountered in the form of quick-sand. The hammers weighed from 1,000 to 4,500 lbs.; the final fall varied from 35 to 40 feet." Concerning the form of the equation, notice that it makes one portion of the pressure due to impact, vary as the weight of the ram, while a second part varies as the square root of the height of the fall or the velocity, and a third portion is constant whatever the weight of the hammer or the height of the fall. It is difficult to see what the conditions are which make this division of the pressure possible. Notice also that the formula gives a negative or imaginary result when $(W + 0.228\ \sqrt{F}) < 1$;

* Mechanics of Engineering, p. 699.

† Republished in 1881, by the U. S. Corps of Engineers, as No. 5 of Papers on Practical Engineering.

‡ Pocket-Book, p. 158.

§ New Mechanics, p. 134.

‖ Jour. Frank. Inst., 3d Series, Vol. 55, p. 101-2.

the author of the formula provides for this limit by the statement that "the formula is not applicable to rams weighing less than one ton." Consequently it is inapplicable to many cases likely to occur in practice. This limitation is remarkable when it is remembered that it was deduced from experiments made with rams weighing from 1,000 to 4,500 pounds. Finally notice that since the penetration per blow is not used, it is inapplicable to any soil differing from that for which it was deduced—quicksand. This formula is not general, and must be used with great caution. It comes under the general case illustrated in Fig. 3. In conclusion, it is only fair to say that the author of this formula in the original memoir distinctly stated its limitations, and therefore is not responsible for its frequent misuse.

Trautwine's formula is* $P = \frac{0\ 023\ \sqrt[3]{h\text{ ft.}}\ W\text{ tons}}{d\text{ inches} + 1}$. Without taking time to make a minute comparison, which the reader can readily do for himself, between this and the rational formulas, equations (3), (4), and (5), it may be stated that if the method of deducing the latter can be relied upon at all, Trautwine's formula is not of the correct form. This difference of form is important, as a little reflection will show; for example, if a light ram with long fall be used on a long heavy pile the penetration (d) may be nearly or quite zero, and consequently the bearing power will appear to be nearly infinite, while in fact it would probably be but a few times greater than the weight of the ram. It is not stated how it was deduced; but in the two cases cited, it agrees remarkably closely with the results of experiments made on piles driven into soft mud at the bottom of a river. The agreement with the only experiments cited as proof of its reliability is so close as to raise the suspicion that the constants were deduced from these two alone; if this is true this formula will come under the general case illustrated in Fig. 2. At any rate, it is applicable only to piles driven into soil similar to "soft mud at the bottom of the river."

§ 9. The tabular view on the following page will show the divergency of the most common formulas. Bear in mind that of the first eight, all of which are generally classed as being derived from experiment, only the last two—McAlpine's and Trautwine's—were derived from experiments on actual piles.

The first example is the somewhat celebrated Proctorsville pile, which was tested, and bore 59,618 lbs. without moving, but moved very slowly under 62,500 lbs. This is the second experiment used above in finding the value of q, and also one of the two experiments referred to in connection with Trautwine's formula. The hammer weighed 910 pounds, and fell 5 feet; the penetration was $\frac{5}{8}$ of an inch. Notice that Mason's formula agrees fairly well with the actual load; probably this is an example under the general case illustrated in Fig. 2 or in Fig. 3. In applying the last three formulas it was assumed that the last blow was struck on sound material, which clearly was not the case.† If the last blow had been struck on sound wood the penetration would have been

* Pocket-Book, Ed. 1885, p. 643.

† Circular of the office of the Ch. of Engrs. U. S. A., Nov. 12, 1881, Pile Foundations and Pile-Driving Formulæ, page 3, table of penetrations.

Name of formula.	Formulas.	Bearing. 1st ex.	Power. 2d ex.
Haswell's......	$P = 4.426\ W\ V$..................	72,000	352,800
Beaufoy's.....	$P = 0.500\ 3\ W\ V^2$..................	147,000	1,600,000
Sanders'......	$P = \frac{Wh}{d}$ N. B.—The factor 8 of the denominator is here omitted....	146,000	1,600,000
Mason's......	$P = \frac{W^2 h}{(W + w)}$; W = weight of the pile....	52,500	886,000
Nystrom's 1st.	$P = \frac{W^3 h}{d\,(W + w)^2}$; W = weight of pile.......	19,000	490,000
Nystrom's 2d .	$P = \frac{3}{4}\,\frac{wh}{d}$	9,000	1,200,000
McAlpine's....	$P = 80\,(W + .228\ \sqrt{h} - 1)$	minus.	185,000
Trautwine's...	$P = \frac{0.023\ \sqrt[3]{h}\ W}{d + 1}$.	58,300	219,000
Rankine's......	$P = \sqrt{\frac{4\ Wh\ S\ E}{l} + \frac{4\ d^2 s^2 e^2}{l^2}} - \frac{2\ d\ s\ e}{l}$	128,000	851,000
Weisbach's....	$P = \frac{H\ H}{H + H}\left(\sqrt{2\ \frac{H + H_1}{H\ H_1}\ \frac{Wh + d^2}{}} - S\right)$; $H = \frac{S\ E}{L}$, $H_1 = \frac{s\ e}{l}$........................	111,000	598,900
Baker's........	$P = \sqrt{12000\ Wh + 36000000\ d^2} - 6000\ d$..........	129,000	686,000

much greater, and the bearing power correspondingly less; assuming the penetration for a blow upon sound wood as twice the recorded value, will give almost exactly the bearing power found by experiment.

The second example is an imaginary pile, although the conditions are those of ordinary practice. It is given to illustrate the divergence of the different formulas under different conditions. The hammer weighed 1 ton, and fell 25 feet; the remainder of the data is as before.

§ 10. It is claimed for the formula deduced above that it is more simple in form than any other rational formula, that it is as easily applied as either of the formulas deduced from experiments, and that it is far more general than many of the empirical formulas. The value of q was deduced from purely theoretical data, and some evidence cited to show that it agreed fairly with experiment. No data are available to satisfactorily determine the quantity, but no data have been found showing that the value deduced from a theoretical basis is seriously in error. The question for the engineer to decide is whether he is better off with a general formula of correct form and approximate constants, or with a formula incorrect in principle, having unknown limits and approximate constants? If any one knows of any data or will make any experiments suitable for the purpose, the writer will gladly discuss them and deduce a value for the term q in the preceding formula.

ELLIS SYLVESTER CHESBROUGH,

HONORARY MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS. DIED AUGUST 18, 1886.

A Memorial by a Committee of the Society.

Although many extended memorial notices of Mr. Chesbrough have appeared elsewhere, it seems proper that this society, which has lost in him one of its earliest and most distinguished members, should put on record a brief statement of its appreciation of his worth. His public life and varied professional services have already been so fully enumerated that this tribute will be limited to a consideration of his personal traits and characteristics.

The most noticeable trait of Mr. Chesbrough's character was his intense, almost morbid, conscientiousness. Most men mean to do about right, but Mr. Chesbrough seemed to consider his every action to see that it should be exactly and perfectly right. This trait he inherited from his father, who was noted for his probity. His father was among the earliest of railroad contractors in this country. It is related of him that once when he built a piece of railroad in Massachusetts, the officers of the road had such confidence in him that they did not consider it worth while to make any contract, but simply paid such bills as he presented.

The absolute uprightness of Mr. Chesbrough's character influenced for good all about him. It was fortunate for Chicago that amid the demoralization of city politics there should be one officer whose probity was unquestioned and unquestionable ; one man whom nobody dared to approach with any improper motive, or, as one Chicago contractor expressed it, whom "nobody would dare to touch with a twenty foot pole."

Goodness, by itself, does not make an engineer, and Mr. Chesbrough became the most distinguished engineer in the country. This was because he inherited and developed that combination of faculties which constitutes a great engineer. He had the power of imagination which enabled him before he began any work to see it as it would be when completed, and to see also the effects it would produce, and how it would be influenced by external conditions. He had the rare power of originating. It now seems the most natural thing for cities bordering on the great lakes to get their water supplies by tunneling out from the shore, yet this method might not have been adopted for a century had not Mr. Chesbrough first thought of it. He had that instinctive knowledge of men and materials which enabled him to select and use them both to the best advantage.

It is to be noted that Mr. Chesbrough did not receive in his youth that education in technical schools which now is considered so important a preliminary to an engineering career. He did not even serve an apprenticeship under some older engineer, as was the fashion in his day. He used to express regret that he had not had better opportunities for study of mathematics and kindred technical subjects. But he always was studious, and it is difficult to see wherein he lacked anything which he might have gained from the text books.

All his life Mr. Chesbrough was a very hard worker. Doubtless he worked too constantly, and would have been the better for more relaxation. He gave his best years and his ripest experience to the city of his choice. As City Engineer of Chicago he was generally overworked, often amid uncongenial and harassing surroundings. The worth of his service was unappreciated except by a few stanch friends. But his public spirit, his love of his profession and his desire to carry out properly the works which he had designed to benefit his fellow citizens kept him at his post for many years when he might have gained more fame and more money in other ways.

Mr. Chesbrough was gentle and considerate to all men, and especially so to his subordinates, to whom his tone was one of almost womanly tenderness. Many members of this society who have worked under him will always remember with affection his unfailing courtesy and kindness.

After a lifetime of hard and successful work, Mr. Chesbrough died a comparatively poor man. He constructed works which made fortunes for others, he cared for the expenditure of millions, he saved much for his fellow citizens, but he made little money himself. He left behind him, however, what is better than money and what money cannot buy : noble achievements, an unblemished reputation, tender memories, and an example which is an inspiration to us all.

VIEWS ON GRADES AND GRADE SYSTEMS FOR CITIES.

By Barnabas Schreiner, Member of the Western Society of Engineers.
[Read January 4, 1887.]

That branch of municipal engineering which should receive the most careful consideration of the city engineer is undoubtedly the establishment of street grades. It requires a thorough study of the topography of the place and the necessities and requirements of surface drainage, sewerage and of the public travel and traffic, and a full inquiry as to the proper relations of the street grades to the abutting property. It is in this last regard that public and private interests are seemingly coming more frequently into strong opposition than with any other branch of municipal engineering. Surely, the peculiar local interests will vary and demand diversified considerations, but very often strong influence will be brought to bear to mislead the engineer to make grades suitable to personal notions, or to induce the City Council to undo the work of the engineer in the interest of blind selfishness ; for such reasons grades will very often be adopted on the compromise plan, disregarding scientific principles and practical experience, creating incongruities irreparable. The grade plan, when deliberately planned, should inflexiby be carried out, as every disregard of the teachings of science and past experience will sooner or later result in financial loss and endless litigations.

To illustrate the correctness ot these statements allow me to refer to one of the several cases that have come to my notice. The grade system of the city of Des Moines, Iowa, originally fixed the elevation of the intersection points of the centre lines of "crossing" and "meeting" streets, and of such other points in these centre lines as were considered necessary ;

and it was conditioned that the grades of the building lines opposite these centre lines be of the same gradient and elevation. The sidewalks must, of course, have the necessary fall toward the curb line and the gutter must be of such depth below top of curb as was found to give sufficient space for the storm water, and the street surface formed the part of a circle (segment), the apex of which came to be about 9 inches below the building line. The application of these theories could not fail to create discrepancies of a serious character, as can easily be shown.

Suppose two streets AB and BC are crossing each other and their centre lines intersect at B. Let the grade be given by the elevations of the points A, B and C above *datum*, and take for convenience $AB = BC = d$; the width of each of the streets $= w$, and let B be greater than A and C be greater than B, so that the differences of elevations of points A and B $= B - A$, and of B and $C = C - B$. The ratio of fall or rise for the length of half the width of the street $\left(= \frac{w}{2}\right)$ will be found for street AB

$$x = \frac{w\,(B - A)}{2d},$$

and for street CB

$$y = \frac{w\,(C - B)}{2d},$$

so that the elevation of the inclosed corner would be either

$$E = B - x = B - \frac{w\,(B - A)}{2d}, \text{ or}$$

$$E = B + y = B + \frac{w\,(C - B)}{2d}.$$

Which of these two values should now be taken as the elevation of this corner? In fact, both elevations have been applied alternately, and the consequences I need not mention.

To remedy this defect, a new ordinance stipulated that certain streets shall be leading streets, or, in other words, the stipulations of the original ordinance, that the elevation of the building line [or street line] should be the same as the (imaginary) centre line grade, shall only be applied to certain parallel streets, and the grades of all streets crossing these had to conform thereto. This change was, in fact, worse than the former evil, as an example will readily show:

Sixth and Chestnut streets are crossing each other; Sixth street is "a leading" street. The elevation of the intersection of the centre lines is fixed at 57.00; a point in centre line of Sixth street, 178 feet south of the first point, is fixed at 47.00, and another point in the centre line of Sixth street, 200 feet north of the intersection point, is fixed at 76.00 feet above datum plane.

These data will give the elevation of the S. E. corner, and the S. W. corner at 55.147, and the N. E. and N. W. corners at 60.135 above datum plane [the street being 66 feet wide].

This places the north sidewalk practically 5 feet above the south one.

To accommodate one or more property owners' desires we find on Second street a depression about the middle of the block of 12 feet below the next higher point, and a sewer on that street required a cut of 20 feet for a considerable length, as the locality beyond the depression has

no other outlet for sewerage. On an adjacent street we find in a block a rise of 15 feet in 120 feet only to run down hill in the other half of the block, and this for no other reason than to save the owner the removal of perhaps 100 yards of ground, and on Seventh and Chestnut streets we find the gradients of four streets running down to the same point, causing an accumulation of storm water, liable to cause considerable damages at any time—as the past has sufficiently proven. The only justification for such a bad arrangement is the plea of one wealthy man, not to make him fill the lot.

These are only a few of the numerous instances, many of which are even of a more serious character. Many other cities are suffering from similar work which inexperience, want of judgment, lack of independence and selfishness have accomplished, as an impedient to the growth of our larger cities.

In establishing street grades, the engineer or surveyor should not share the popular illusion that grades are only to serve as a "rule" by which to set the water table, and that the lot owner is the only person interested in this matter.

The points to be attained by street grades are :

I. The securing of proper surface drainage of the streets.

II. To secure proper facilities for the construction of an efficient sewer system at moderate cost.

III. Proper gradients for the accommodation of public communication and traffic.

I. Surface Drainage.

The grades of the streets should be so arranged as to :

1. Facilitate the flowing off of the storm water at a moderate velocity. Such gradients as would cause the storm water to flow with great velocity should be avoided, as strong currents would damage the street surface, and are liable to cause overflows and other damage to streets and property.

2. Grades should be further so arranged for the different streets as to avoid the accumulation of large masses of storm water at any one point which would be likely to cause overflows and damage to property, creating liabilities to the corporation.

3. Wherever possible, conduct the surface water along the shortest route to its outlet or point of discharge.

4. Avoid the frequently made mistake to direct the surface water toward depressions or dips in the ground, often called "Runs," and wrongly taken for natural water-courses, as all such depressions will, in the course of time, be filled up and occupied by residences and other buildings, and the course of the surface drainage must ultimately be changed, usually to the detriment of the corporation treasury.

II. Considerations in Regard to Sewerage.

When establishing the street grades much can be done toward facilitating and devising an efficient sewer system at a minimum cost.

Thousands of dollars have often to be expended in the building of large additional sewers in deep cuts, resulting from the injudicious adjustment of grades, which could and should have been avoided by proper con-

sideration of the circumstances and the formation of the surface of the ground on which the city is located.

III. Proper Gradients for the Accommodation of Public Communication and Traffic.

That steep gradients should be avoided to secure the streets against washouts and damages generally, I have already stated. Other reasons why steep gradients should be [avoided are: safety to the traffic and travel, and proper accommodation as ways of communication.

The sidewalks should have no greater inclinations toward the gutter than is indispensable for shedding the rain water into the gutter, as the increase of the fall will decrease the safety to the people. The access to the sidewalks from the street, and *vice versa*, should be easy as well as perfectly safe, and the road-bed should be level in the line of cross-section.

No clamor of the selfish property owners should be listened to, if the engineer would mind the interest of the public. Well-selected gradients have always proved themselves as enhancing the value and salability of the abutting property. Cuts and fills deserve only a secondary consideration. The past has proved by innumerable instances that emidences have disappeared and low grounds have been raised and transformed into valuable property with less expense than the cost of litigation caused by illy conceived grades, which public interest demanded changed thereafter.

It is hardly necessary to call the attention of the engineer and surveyor to the fact that a correct topographical map of the place is the first requirement, and that the study and final determination of the grade system in question should embrace and be based upon the whole terrain.

The selection and location of the datum plane is of no important consequence, but when once located it must be secured by durable and reliable benches. The elevation of the different points should be, whenever possible, so selected as to give the gradient in per cents of the horizontal distance. It is also of little consequence whether the elevations are given for the street centre or the "property lines," but when once a mode is chosen, it should consequently be carried through systematically. But under all circumstances should the "*intersections*" be laid level, as this is the only proper arrangement to guarantee the proper construction of street surface and its appurtenances.

DES MOINES, Ia., Dec. 26, 1886.

THE FUTURE DRAINAGE OF ST. LOUIS.

BY ROBERT E. MCMATH, MEMBER OF THE ENGINEERS' CLUB, OF ST. LOUIS.

[Read March 3, 1886.]

The drainage of St. Louis, while peculiar in some respects, has not hitherto presented the difficulties which have been encountered in other cities less favored in topography; hence, the questions of system, combined or separate, of disposal, by irrigation, precipitation or other means, have not heretofore been matters of local interest.

As Mr. Robert Moore told us in his paper, JOURNAL OF ASSOCIATION ENGINEER SOCIETIES, February, 1885, sewering had its beginning in St. Louis at a comparatively early date under the stress of necessity. That necessity was readily met by a series of sewers, draining what is now the central and older part of the city, extending from the river back to about Sixth street, flanked and embraced on the north and northwest by the more extended basin drained by Biddle street sewer, a basin which had no visible natural outlet, and on the south and southwest by the Mill Creek Valley. As the city grew, other sewers to the north and south were added, all emptying into the Mississippi, with drainage areas of greater or less extent, until the city, as its limits were defined previous to 1870, had a sewer system laid out and partly executed fairly capable of draining nearly all its territory. By legislation in 1870 the former City of Carondelet was consolidated with St. Louis, and later by the adoption of the scheme and charter of 1876 the territorial area was increased from 13.94 to 61.37 square miles. It often appears that conveniences which men use have grown out of pre-existing conditions, rather than been produced by design, and it sometimes appears that the result of such growth is as well suited to the necessities of the case as the most elaborate design could be. But, in St. Louis as in other cities, the results of growth in sewering are not such as can be perpetuated, much less accepted as precedents for future imitation. Experience of the intervening years has taught many lessons concerning sewering. The changed habits of men in their homes and business present new conditions which must be taken into account, as also a rational foresight of things yet to be, when considering the future drainage of this or any other city.

A primary question is: How shall sewage be disposed of? Precisely what weight should be given this question it is now difficult to say. If the germ theories of disease now so prominent should prove true, the waste products of the human system must be destroyed beyond the possibility of the survival of a germ. If this is to be done a separate system more rigid than has heretofore been urged must be adopted. But if, as is probable, the suspicion now attached to sewage is exaggerated, then we may still trust to attenuation of danger by dilution of excrementary matter with other waste and abundance of water. That is the citizen of the future will use water more freely than he of to-day in about the proportion which the progress of sanitary science and civilization of his time may bear to that of to-day. Water carriage of offensive matters may, therefore, be accepted as a finality for St. Louis.

Estimating the daily quantity of sewage from the city as equivalent to the water supply, 500 cubic feet per second may be taken as the outside future figure from St. Louis. This discharged into a river whose minimum flow is certainly over 35,000 cubic feet per second will not seriously pollute that river. The rapid current will insure commixture, aeration and consequent speedy breaking up of organic compounds. Chemically the water along the Missouri shore ceases to show sewage pollution eight miles below the last sewer. That is, Prof. W. B. Potter found no more chlorine and ammonia in water taken at Quarantine Station than in water taken above the city. Since there is no present reason to suppose that any town requiring a water supply from the river

will grow up within fifty miles below St. Louis, there is no reason to anticipate any serious objection in the future to the discharge of sewage into the Mississippi, unless it come from the pollution in front of the city itself, where the sewage will skirt the west shore and floating bodies be liable to lodge along the bank or collect in eddies caused by boats, etc. Hence St. Louis would be the first and greatest sufferer and in self-defense would have to carry sewage out to the main current. At high stages, this is now done along the improved front. The primary question may therefore be answered. Sewage may be discharged into the Mississippi in the future as now without purification.

The delivery into the river will present some difficulty along those parts of the front where the street grades are but little above high-water level. That is, for all outlets north of Branch street and, to a lesser degree, those between Convent street and Arsenal street. Sewers throughout these parts of the front, if laid at the usual depths below street grade, must, for a considerable part of the year, be subject to back water from the river. This is now the case with Salisbury street, Bremen avenue and Ferry street sewers to an extent that not only deprives the property as far back as Broadway of cellar drainage for weeks at a time, but also fills the sewers with an accumulation of deposit that is not wholly cleared out at any time. The water sealed state commonly lasts from March to August. Still worse, the river is inclined to deposit a bar in front of the city from Ferry street to North Market street, and as a consequence the sewer outlets named are surrounded by deposit often ten feet above their bottom grade. At such time their actual connection with the river is by a crater formed and maintained by the water issuing from the sewer, boiling up, not running out. Obviously the sewers have a hard time to maintain these openings, and, since no help can be given them, there is serious danger they may fail. If by accident to the water works or distribution the supply of water to the north part of the city was cut off for one day during high water the three sewers named would probably be sealed up. Fortunately the sewers receive frequent vigorous flushes from local heavy showers during the high water season.

Salisbury and Ferry street sewers originally emptied into Gingrass Creek, a little west of where Hall street is now located ; their extension to the river carried the new outlets to a low level near low-water mark, though made with flat grades. These sewers afford instances where growth has resulted badly. Bremen avenue was built with river outlet at low grade, and is, therefore, bad design from following a growth precedent.

It is now evident that these flat areas along the river front should have been traversed by shallow sewers to carry surface water and sewage from the high grounds, delivering into the river at as high a level as practicable, and by a system of separate sewers to carry the local sewage and cellar drainage, if the use of the property should render such second system necessary. These flat areas, presumably, will in the future be occupied by railroad yards, storage grounds and manufacturing establishments ; it is, therefore, probable that shallow drainage will suffice. If deep drainage is attempted, the sewage must be conducted to one or

more convenient stations, and pumped during times of high water in the river.

A second system of sewers will also be needed in the business section of the city to satisfy the demands of modern modes of business for basements and sub-cellars. The early sewers were laid with insufficient depth. A deep sewer was built on Ninth street as an incident to the erection of the new Custom House, several private deep drains have been laid eastward from Fourth and Fifth streets to furnish these facilities in special cases, but a general provision should be speedily made. A reconstruction of Thirteenth street sewer as a deep sewer should be made at an early date.

Thus much concerning the future drainage of the St. Louis of yesterday.

The city yet to be will probably lie within the present corporate limits, with perhaps outlying suburbs along the lines of the converging railways. So far as such suburbs lie within the water-shed of the River Des Peres, their drainage will depend upon that of the city. Their needs must therefore be anticipated, and provided for in the plans adopted.

The boundaries of the city, as defined by the scheme and charter, were wisely located to include the bed of the River des Peres and the bank of the Mississippi as far north as the Chain of Rocks.

Reference to a map of the surrounding territory shows that there is a divide near where the Wabash Railroad crosses the Natural Bridge road, between water flowing northwardly to Maline Creek and southwardly to River des Peres. Maline Creek, after junction with a branch which skirts the north side of Calvary Cemetery, and with another which passes between O'Fallon Park and Bellefontaine Cemetery, in former days, continued a southerly course and emptied into the Mississippi near Salisbury street, under the name of Gingras Creek, with the drainage of about 40 square miles. It now empties into the Mississippi about two miles above the water-works. The branch running between O'Fallon Park and Bellefontaine Cemetery now has a virtually independent connection with the river. In the lower part of its course it is known as Harlem Creek, but above the Natural Bridge road it retains the ancient name of Marais Castor. Harlem Creek drains about 6 square miles.

The north fork of the River des Peres enters the city limits to the northwest of Forest Park with the drainage of about 20 square miles, and in a further course of 8 miles receives about 14 square miles more. The south fork comes from the westward and drains about 35 square miles. The united stream receives additional drainage from the south and west from 34 square miles, and from 10 square miles within the city limits, finally reaching the Mississippi with the water coming from 113 square miles. Ordinarily, the River des Peres is but an insignificant stream, in time of drouth scarce could be called a stream, but at times of heavy rains it fills its channel and overflows its banks. Obviously, such a stream cannot be covered in as a sewer, nor can it be allowed to receive sewage and remain an open channel with stagnant pools in summer. It traverses Forest Park as a prominent feature in the landscape, and it skirts the southern part of South St. Louis. At neither of these parts could a polluted stream be tolerated, if it might in other parts of the course.

The divide between the affluents of Harlem Creek and those of the River Des Peres runs a little north of Easton avenue from Taylor avenue west to city limits. The Des Peres and Harlem drainages, therefore, bound the city on the north, west, and south, with the Mississippi on the east. Of the area so embraced, the southwest part, bounded north by Arsenal street, and east by a line drawn south from the Insane Asylum to the Gravois road, is not likely to be built upon. The remaining area I assume to be the site of the city of the future. The area is approximately 44½ square miles, of which about 12 have been sewered. Sewers now begun will, when completed, drain about 22 square miles, and others to be built, emptying direct into the Mississippi, about 1½ square miles, leaving 21 square miles of new territory to be provided for, all belonging to the Harlem and Des Peres basins. Since the completion of sewers already begun will be but carrying out the plans of the past, new features and the possibility of the adoption of other systems than the combined are limited to the following areas :

	Acres.	
Harlem Creek	1,800	Harlem Creek.
Marais Castor	2,000	
Hodiamont avenue	720	Des Peres.
De Baliviere "	600	
Union "	1,000	
Lay "	630	
Des Peres direct	2,050	
Grand Ruisseau	2,900	
Rock Branch to Des Peres	1,700	
Total	13,400	

A natural topographical feature has allowed no choice as to system hitherto, namely, interior basins without visible outlets. Every sink hole is an example on a small scale, but large areas exist which have no outlet, whose depression must be perpetuated in street grades. These require a subterranean conduit capacious enough to carry off the maximum rainfall. Several of these larger basins have been tapped by sewers. These remain as notable examples: the 100 acres belonging to Ferry street area lying west of Grand avenue, this has a present vent through a 9-inch pipe laid through the bounding ridges, and by a large spring at Ninth street and Angelica; the 900 acres west of Prairie avenue, belonging to Rocky Branch area, which now has a precarious vent in a sink between Claggett and Labadie avenues, just west of Prairie; the 630 acres between Taylor avenue, King's Highway, Eastern avenue and Duncan avenue, now having a 9-inch drain into Forest Park, and several spring outlets in the park and east of Taylor avenue; and about 200 acres between Meramec and Maeder streets, Compton avenue and the river bluff. Of these inclosed basins the first three are now being largely built upon. These three basins are unlike others, in that the surface is unbroken by the sink holes that in other areas are scattered much as pits on the face of a small-pox patient ; in these the surface slopes gently toward one centre.

Sink holes originally formed a prominent topographical feature in the high parts of the territory defined by Grand Avenue, Meramec street, Stringtown road and Dover street. Outside of this boundary the country generally has the features of a prairie, and in early days was known as

Grand Prairie, Cul de Sac, Prairie des Noyers, and Carondelet Common Fields. The change is not only in contour, but in soil. The subsoil inside is brick earth, loess, with a thin coat of mold; outside, the soil is a dark, vegetable mold, underlaid by impermeable clay. This difference of soil has to do with the urgent necessity for sewering, as the prairie districts are built upon. It will be remembered that the main drift of the city's growth is toward the prairies, attracted in some degree by the smooth surface and its conformity to grade without cost.

The sink hole districts are higher in level and were naturally thoroughly drained. The ridges between sinks were never thoroughly wet, and could be used for building ground without fear of damp cellars or malarial exhalations. Our people found by experience inside of Grand avenue, that they could, as pioneers, press into the suburbs without risk to health, and, failing to note the difference in soil, have assumed that this could be done in the extended limits. The residences are now going into districts where a dry foundation is a rarity, where the ground water level is often not more than three feet below the surface. It remains to be seen whether sewers can be built fast enough to avert an outbreak of preventable disease. The wish on the part of the Board of Public Improvements to meet this urgent necessity has led them to propose that sewers shall be built by the property benefited, and in large districts.

One large district of 530 acres has been laid out and work begun.

The conditions having been stated, the question remains : What shall be the general plans of the future? I do not assume to speak by authority, but simply state what appears to me the best plan.

The choice lies between :

1. Continuation of the combined system as now practiced. This I set aside as impracticable since River des Peres cannot be made a sewer—open or covered.

2. Adoption of a separate system, as that system is advocated and understood. This I consider unsuitable, since the sub-water courses are too long for storm water to be carried in street gutters, hence an attempted separate would lead to a double system.

3. A combination. Small sewers at the summits and upper slopes, with combined sewers along the sub-valleys delivering foul water of ordinary weather into intercepting sewers with overflows to open channels for storm water.

I consider it essential that the open channels, which would be the River des Peres, Harlem Creek, and Marais Castor, to about Clara avenue produced, should be kept free from pollution. I know no way in which this can be secured unless the channels and their immediate banks become the property of the city. To guard the River des Peres from pollution intercepting sewers must at an early date follow the right bank from the Mississippi to mouth of Grand Ruisseau, and eventually to the mouth of Rock Branch ; the left bank from Arsenal street to south line of Forest Park ; and along the north line of the park.

Harlem Creek Valley will require an intercepting sewer from the Mississippi to Natural Bridge road and Marais Castor, from that point to near Clara avenue. These intercepting sewers are not to follow the meanders of the streams, but take the shortest practicable course. If

cost of sewer construction be set off against cost of land an economical balance will be found in favor of a liberal land condemnation. I do not say that Harlem Creek could not be covered in; but the cost would be great, 2½ miles of large sewer, whose cost cannot be estimated at less than $500,000; whereas an intercepting sewer would not cost more than $100,000, and the land taken would be extravagantly valued at $50,000.

If the plan of intercepting sewers for sewage, and open channels for storm water be adopted for the larger streams, then its extension to the minor creeks, Marais Castor, Grand Ruisseau and Rock Branch is also suggested.

To carry out this or indeed any rational plan, will require the wise and early adoption of a general plan of streets and drainage lines that shall conform to the topography, so as to afford surface drainage by streets to the main drains.*

The plan which I suggest for the future drainage of St. Louis comprises:

1. Sewers carrying house drainage and storm water from the high lands to and along the minor watercourses.

2. Intercepting sewers receiving the ordinary flow from several sewers of the preceding class and carrying it to some suitable outlet. Overflow to pass into open channels when size becomes inconvenient.

3. A sewer from near Union avenue, running east along north line of Forest Park, and thence through the ridge to a connection with Mill Creek sewer, into which the foul drainage of the Lay and Union avenue districts would fall by gravity, and that from De Baliviere and Hodiamont districts, and the suburbs that may grow up on the north branch of Des Peres, be pumped; lift, about 25 feet. Also a sewer along the slope to the Des Peres from near Arsenal street northeastwardly to the Mill Creek sewer, to which the sewage from the area south of Forest Park and from suburbs developed in the district drained by south branch of Des Peres shall be pumped; lift, about 60 feet. In this case purification is an alternative to be considered.

4. Storm water conduits from the depression on Lay avenue leading into the Des Peres, and from the south part of the Mill Creek basin, following near the line of the railroads into the Des Peres, to divert a part of the water from Mill Creek sewer, which will be overtaxed. Also if it should be found necessary to relieve Rocky Branch sewer, a conduit to Harlem Creek could be built at less cost than a second sewer parallel to the one now existing.

The accompanying map shows the several drainage areas. It must not be supposed that the boundaries or locations are fixed, for they have been sketched in from eye survey only.

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* Such a general plan was contemplated by the charter, and it was made one of the duties of the Board of Public Improvements to prepare the plan, but the duty has not been performed, chiefly because no appropriations for surveys have been made. The cost of topographical surveys has been so much reduced by the transit and stadia method that there is no reason for further delay. Triangulation and topography may, and should, precede the cadastral survey.

Were the cost tenfold what it need be, the investment would pay the city manifold in diminished cost and increased facility for drainage.

The contours shown on the accompanying skeleton map give an imperfect idea of the topography of part of the city.

Table of sewer areas actual and suggested :—

No. 1. Several small sewers, direct to river, all built.
" 2. Biddle street sewer, drainage nearly complete.
" 3. Small sewers, direct to river, all built.
" 4. Chambers street sewer, drainage nearly complete.
" 5. Benton street sewer, drainage nearly complete.
" 6. Small sewers, mostly not built.
" 7. Salisbury street sewer, drainage nearly complete.
" 8. Bremen avenue sewer, drainage nearly complete.
" 9. Ferry street sewer, main sewer unfinished.
" 10. Prairie avenue sewer, main sewer unfinished.
" 11. Harlem Creek, large area not yet occupied.
" 12. Rocky Branch sewer, main sewer unfinished.
" 13. Hodiamont avenue sewer, area not occupied as yet, part lies outside of city limits.
" 14. De Baliviere avenue sewer, area filling rapidly.
" 15. Union avenue sewer, area developing.
" 16. Lay avenue sewer, area filling rapidly.
" 17. Mill Creek sewer, main trunk sewer nearly complete. Branches built in east half of area.
" 18. Contains growing manufacturing and residence suburbs, no sewers.
" 19. South slope to River Des Peres, growth slow.
" 20. Rutger and Miller street sewers, drainage complete.
" 21. Carroll street sewer, drainage nearly complete.
" 22. Southeastern sewer, drainage nearly complete.
" 23. Trudeau street sewer, drainage nearly complete.
" 24. Barton street sewer, drainage nearly complete.
" 25. Louisa street sewer, drainage nearly complete.
" 26. Arsenal street sewer, area about half sewered.
" 27. Utah street sewer, area mostly unsewered.
" 28. Southern sewer, little used as yet.
" 29. Uncertain, probably will be joined to 32.
" 30. Grand Ruisseau, large unoccupied area.
" 31. Will drain to river.
" 32. Grundy street sewer, north end of South St. Louis.
" 33. Quincy street sewer, area well occupied, sewer needed.
" 34. Stein street sewer, sewer built, area partly drained.
" 35. Will drain direct to river.
" 36. Natural outfall is by the Des Peres, an intercepting sewer must be provided to take the dry weather flow from this area and from 30 and 37.
" 37. Rock branch, like the last, but sewering a remote contingency.

The figures 37 were unintentionally omitted from the map. The area lies west of No. 30.

NOTE.—Since the paper was written a general plan has been adopted by ordinance, embracing the areas designated as Nos. 13, 14, 15, 16, west part of 17, 18 and 19, in accordance with the suggestions above. Of the area embraced in the plan, 13,200 acres, about 5,000 will be drained in the usual way, 4,550 will drain sewage to intercepting sewers and be provided with storm overflows, 2,300 acres by a separate system, and 1,350 acres, being park, will not be sewered.

TOPOGRAPHICAL MAP

OF THE

CITY OF ST. LOUIS

SHOWING THE

PRINCIPAL DRAINAGE DISTRICTS.

Scale, 4,400 Feet = 1 Inch.

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EFFICIENCY OF CABLE ROADS.

ITS VARIATION WITH LENGTH OF CABLE AND OTHER ELEMENTS OF THE CONSTRUCTION.

BY JAMES A. SEDDON, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read February 2, 1887.]

I suppose almost every engineer has heard more or less loose talk about cable roads, both by their advocates and their opponents. The balancing of up and down grades, and easy increase in service, on the one hand, and the loss of power in pulling a heavy cable for nothing, on the other, and so on *ad infinitum.* But, unfortunately, the saving or the loss in any case has rarely been reduced to actual figures.

Having had my attention called to some questions of the efficiency of this method of transportation, I could find very little that had been published on the subject, and some of that little misleading. I have therefore gathered together what facts I could, and have used them in connection with a fairly full theoretical discussion, in the hope of either inducing the publication of further facts, or stimulating the collection of further data, which would be very useful to the engineer in planning and the superintendent in operating this class of roads.

As in the case of the beam, it is apparent that there is a limit to the length of a cable, beyond which it could not be made to draw its own weight, and that as it increased in length the efficiency, or "power expended in drawing cars," divided by "total power expended," must decrease. The purpose of this paper is a consideration of this decrease in efficiency, together with the differences in efficiency for different factors of safety with which the cable is worked, and the differences in efficiency for different values of constants dependent on the construction of the road (size of sheaves, etc.).

The first, change of efficiency with length of line, is an important factor in the location of power stations, for it is simply an equation between cost of wasted power and cost of power stations whether a line should be operated from one or from two stations, or, in case of one station, what extra expense should be incurred in cost of site to place the power station about the middle of the line and operate it with two cables.

The second, differences in efficiency for different factors of safety, is one step in the determination of what would be exactly the most economical size of cable to use for any given road. The second step would be the life of cables with different factors of safety. This second step will probably only be determined slowly by practice.

In the third, differences in efficiency for differences in constants of construction, the writer regrets that he can only show what differences in efficiency may be thus caused; he at first hoped to be able to connect this change in the constant with the specific differences in construction, such as size of sheaves, number of curves, depression pulleys where there were any, etc. The scattering data which he could collect, however, was insufficient for this. But he hopes that the large effect that

differences actually found in this constant have on efficiency may call attention more especially to this subject, so that this change may be soon quantitatively connected with its specific causes.

In this discussion, the pull on the cable required to operate the road will be used as offering a simpler method than by horse-power (H. P.). This pull taken in pounds and called P is the difference in tension of the cable on the taut and slack side of the driving drum. P is related to the H. P. required to operate the road by the equation $\frac{P\,v}{550} =$ H. P. where v is the cable velocity in feet per second. In the above, as also through this paper, the small fraction of the power used in running the machinery up to the driving drum is neglected.

This total pull is divided into the pull required to run the cars on the line, and the pull required to run the cable. It may be written :

$$P = P_1 + P_2 \left\{ \begin{array}{l} P_1 = \text{total pull in pounds of the cars.} \\ P_2 = \text{“ \quad “ \quad “ \quad cable.} \end{array} \right.$$

Considering first P_1, it is apparent that, with a given average pull for each car, and with the cars at a given distance apart, comparing one length of line with another, there would be twice as many cars, or twice as much total car pull on a line twice as long, three times as much on a line three times as long, etc. Or $P_1 = K_1 L$, where L is the length of a given cable road in feet, single line, and K_1 is a constant to be determined for each road, from the average resistance to traction per ton of car load, multiplied by the average weight in tons of a loaded car, multiplied by the number of cars on a unit length of road. As used in the final calculations, L will be taken in units of 1,000 feet, so that in this form the equation becomes

$$P_1 = 1{,}000\ K_1\ L \qquad \text{(I.)}$$

The resistance to traction per ton has been made the subject of very careful experimental determinations on steam railroads, but street roads with flat rail heads and different journals present enough variation to make the use of these experiments quite uncertain.

About the only applicable data that I have been able to find on this subject is from a paper by Mr. A. W. Wright in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, December, 1885. In this, from a number of dynamometer measurements, he finds on new steel rails an average resistance per ton for street cars of 15.6 pounds. This is the pull required to keep in motion at about 7 miles per hour, and does not include the extra pull required to start cars. He also gives some experiments of D. J. Miller, M. E., while employed on the Chicago cable road, from which he deduces the pull per ton as 10.95 at about the same velocity, including power to start. He, however, states that in this case the weight of passengers was estimated without a count of their number, and concludes that an overestimate of passengers accounts for this small value of resistance to traction. It does not seem impossible, however, that resistance to traction may be somewhat less for cable roads than what is generally found on horse roads, as the rail on the cable road is generally cleaner.

The resistance to traction per ton on cable roads is a value that could so easily be determined on any cable line by connecting the coach to the

grip car through a dynamometer and dividing mean pull by weight in tons hauled that any attempts to more exactly *estimate* it would be unnecessary. When once well determined it might be considered a constant, as the variation in speed of different roads would probably not be enough to materially affect it. This resistance to traction in pounds per ton hauled being called f_c and neglecting the extra resistance of curves, which would have a special value for each road, the value of K_1 in terms of those elements that must be adjusted to suit the travel will be almost exactly expressed by the following formula :

$$K_1 = \frac{w}{60\ v\ t}\left(f_c + \frac{2000\ v^2}{d \times 2\,g}\right)$$

Where w is the average weight of a loaded train in tons.
v " cable velocity in feet per second.
d " average distance between stops in feet.
t " mean actual time in minutes between trains.
g " acceleration of gravity=32.2.

The above formula requires no further explanation, it being simply an expression for the mean car pull per foot of cable line, the work used in starting cars being distributed over the line, and the number of cars pulling being taken at $\frac{v_1}{v} \times$ (No. of cars on line), v_1 being the mean velocity of the cars. It has been called almost exact; this is because the time that a car was loose on the cable at a stop has been taken as equal to the time lost at that stop. This would be the case exactly if the time used in stopping the car were the same as that used in starting it again. A slight difference that might exist in these times would cause the formula to be in error an inappreciable amount. Also f would not be theoretically constant through the variable velocity of the start. Altogether the possible errors in the formula on any actual road would hardly affect the value of K_1 in the fifth decimal place, or beyond the range to which calculations would be carried.

A tabulation is here presented giving the values of K_1 for those different values of the elements on which it depends. It represents about the range that might be found necessary in the different services for which this class of roads would be built.

In the following table d, or the mean distance between stops, has been taken as 1000 feet. This quantity without very careful statistics for each road can only be an estimate, but as it only enters once to the first power in the smallest term for K_1, moderate changes in it would only slightly affect the above values. In the paper by Mr. Wright, above referred to, he states from his experience on one of the Chicago roads the average distance between stops was in that case 1178 feet. f_c has also been taken in this tabulation as 10 ; this gives for a 7 miles velocity a resistance to traction per ton, including starting, of 13.3 pounds. This value is between that of Mr. Miller's of 10.95, and Mr. Wright's of 15.6 ; the first on cable lines, including starts, the second on horse lines, excluding starts ; but as before stated, no very close calculation can be made on this subject until more data are collected on car friction. However, the object of the above tabulation is to show how the value of K_1 will vary with the more important variables, velocity of cable, average weight of

$$K_1 = \frac{w}{60\,v\,t}\left(fc + \frac{2000\,v^2}{d \times 2\,g}\right) \qquad \left\{\begin{array}{l} w = \text{Average weight of trains in tons.} \\ v = \text{Cable velocity in feet per sec.} \\ d = \text{Average distance between stops} = 1000 \text{ feet.} \\ t = \text{Mean actual time in minutes between trains.} \\ 2\,g = 64.4. \end{array}\right\} fc \text{ taken as } 10.$$

$$= \frac{w}{t} \cdot X$$

TABULATION.

VALUES OF K_1.

v in miles per hour.	X.	$t = 2$	$t = 3$	$t = 4$	$t = 5$	$t = 6$
		$w = 8$.				
6	0.0235	0.0940	0.0627	0.0470	0.0376	0.0313
7	.0216	.0864	.0576	.0432	.0346	.0288
8	.0203	.0812	.0541	.0406	.0325	.0217
9	.0194	.0776	.0517	.0388	.0310	.0259
10	.0190	.0760	.0507	.0380	.0304	.0253
		$w = 10$.				
6	0.0235	0.1175	0.0783	0.0587	0.0490	0.0392
7	.0216	.1080	.0720	.0540	.0432	.0360
8	.0203	.1015	.0677	.0507	.0406	.0338
9	.0194	.0970	.0647	.0485	.0388	.0323
10	.0190	.0950	.0633	.0475	.0380	.0317
		$w = 12$.				
6	0.0235	0.1410	0.0940	0.0705	0.0564	0.0470
7	.0216	.1296	.0864	.0648	.0518	.0432
8	.0203	.1218	.0812	.0609	.0487	.0406
9	.0194	.1159	.0773	.0579	.0464	.0386
10	.0190	.1140	.0760	.0570	.0456	.0380
		$w = 14$.				
6	0.0235	0.1645	0.1097	0.0822	0.0658	0.0548
7	.0216	.1512	.1008	.0756	.0605	.0504
8	.0203	.1421	.0947	.0711	.0568	.0474
9	.0194	.1358	.0905	.0679	.0543	.0453
10	.0190	.1330	.0887	.0665	.0532	.0443

trains and time between trains, and about the actual variation of K_1 that would be found on different roads running trains is covered in this tabulation, though further investigation in car friction might show that these values of K_1 here given were not assigned to exactly the right cable velocity or average weight or time between trains.

In what follows K_1 will enter the general formula as a quantity to which a value must be assigned in each case, which value is determined, as shown above, by the special demands of the service in that case. But in the special investigation of the variations of efficiency with different lengths of road, etc., a value of 0.0812 will be taken for K_1, or the tabular

value of a three-minute service, eight-mile velocity of cable and twelve tons average weight of trains. This is somewhat smaller than the correct value for the St. Louis cable road.

It may be here stated that, of course, about the maximum service must be taken in determining the value of K_1, since size of cable should be designed for this service; and further, that it is only the efficiency for this maximum service that is the subject of consideration in this paper. It is plain that if the size of cable is fixed by this service, and hence power to pull cable is fixed, the greatest efficiency for a given allowable strain in the cable will be obtained at this maximum service, and that from this value the actually realized efficiency may decrease to zero as the cars are more and more nearly all taken off the road. The relation of the actually realized efficiency to this maximum efficiency may be easily determined in any given case, knowing the fluctuations of the service, but a consideration of this is beyond the purpose of this paper.

Having considered briefly the nature of this constant in the equation for the more simple variation of total car pull with length, it will be necessary to consider in greater detail the variation of total cable pull, or P_2, with length. It may be said that P_2 should vary directly with total weight of cable, or $P_2 = K_2$ (cable weight), but to see exactly under what condition this equation exists, it will be necessary to review some of the principles underlying this method of the transmission of power. If in this I am repeating what is familiar to many of you, it is simply to avoid the possibility of being misunderstood by some, and I hope on that account I may be pardoned in explaining, perhaps with unnecessary care, precisely the steps taken.

P_2, which is the force that overcomes the friction resistance to the movement of cable, may be taken as meeting a resistance made up of two elements. First, an element of friction due to the weight of the cable. Second, an element of friction due to the tension of the cable. The first is simply a weight pressure on a number of journals, and for sheaves and journals of a given size may be taken as $f_r \times$ (cable weight), where f_r is the co-efficient of friction for a given pulley and cable weight is the total weight on all the pulleys. Second. The element of friction due to tension would occur mainly at curves, depression pulleys, etc., or wherever a bend in the cable caused the tension under which it was working to bring an extra pressure on the journals. It may be written $\Sigma f_t\,(T)$ where f_t is a constant co-efficient and T is the tension of cable found at any point where such tension was causing additional friction, Σ indicating the summation of all such points. A word now in regard to the laws of this method of transmission of power.

As in the case of a belt, the sum of the tensions on the taut and slack side of the driving drum is constant. If the driving drum were free to move in either direction the tension on each side would become equal. This is called the mean tension, or T_m. When the drum is turned, transmitting a pull to another drum, or as in the case of a cable road distributing it along the line, the mean tension is increased on the side transmitting the pull, and decreased by an equal amount on the other side. These tensions are respectively called T_1 and T_2, and $T_1 - T_2$ is the pull transmitted. For any given arrangement of wraps on the driving drum and a

given mean tension, it is apparent that there is a limit beyond which the excess of T_1 over T_2 could not go. It is the point where any excess of pull would cause the cable to slip on the drum. This limit to the value of pull transmitted is given by the well-known equation between the two tensions.

$$\frac{T_1}{T_2} = e^{f\theta}$$

where f is the co-efficient of friction between the materials of the belt and pulley, and θ is the angle of contact, e being the Naperian base. This is the ratio of greatest economy in transmission of power and would be approximated in practice. The above equation gives simply a definite relation between mean tension, or

$$\frac{T_1 + T_2}{2}$$

and the maximum tension or T_1, as follows :

$$\frac{T_m}{T_1} = \tfrac{1}{2}\left(1 + e^{-f\theta}\right)$$

We will now return to the element of friction due to tension, which was $\Sigma f_t\ (T)$, and assuming, what would always be very close to the case, that the pull was uniformly expended along the straight reaches we would have T_1 decreasing uniformly from the power station to a curve or depression pulley down the line ; also T_2 would increase on the return line the same amount down to this point, so that the sum of the two tensions on the down and up line acting at that point would be $T_1 + T_2$; through the curve it would not be uniform, tension increasing less there on the return line, so that the sum of the tensions would be slightly less at the second curve, etc.; but neglecting this as very small in comparison with thevalue of $T_1 + T_2$, and considering the summation as embracing the points of a double track road, taken opposite each other, two and two, we may write with little error T_m for the variable tension T at any point. Also if we consider the length of the road taken in an imaginary unit, comprising an average amount of this tension resistance, we may replace Σ by multiples of the length in this unit, from which we have

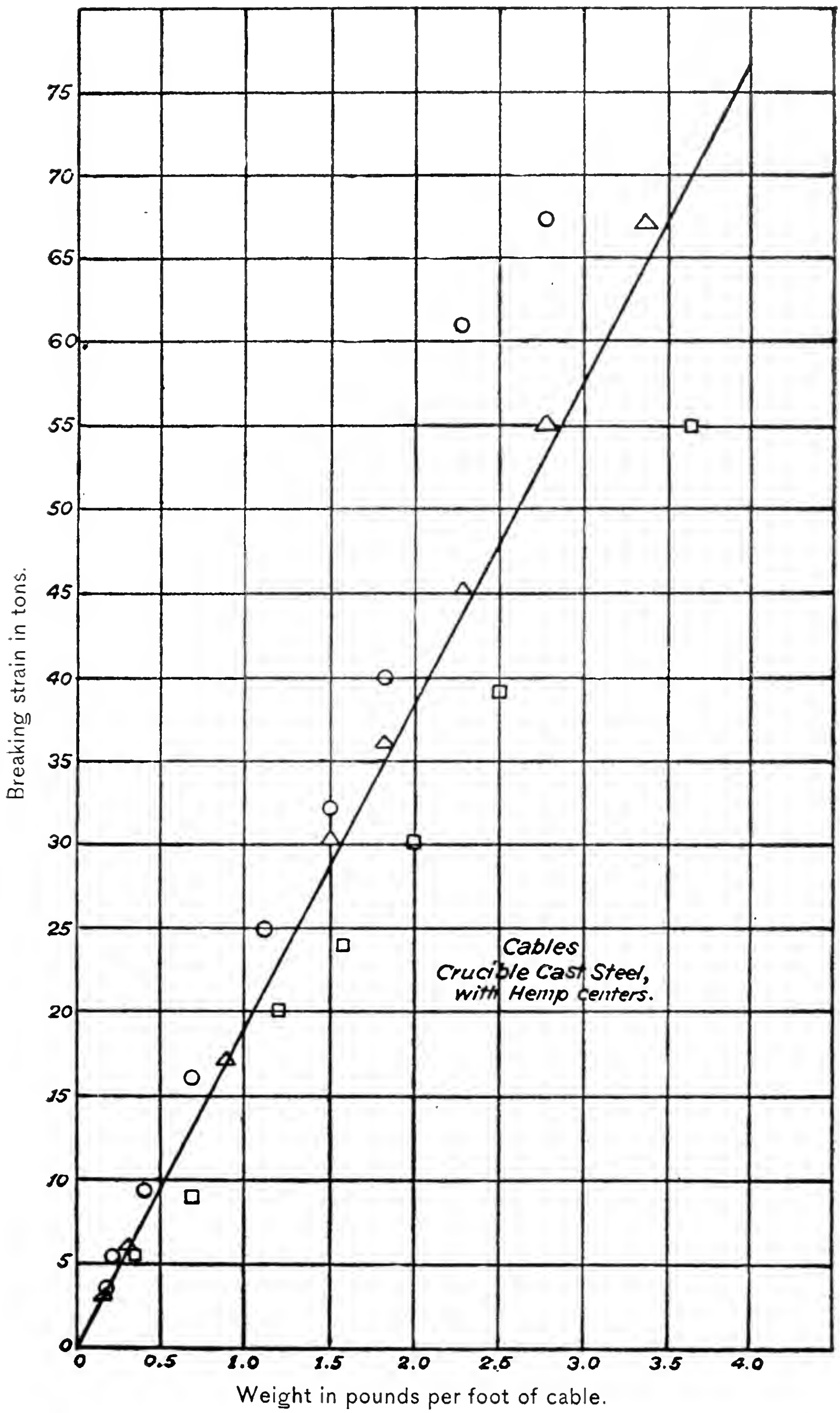
$\Sigma f_t\ (T) = l f_t\ (T_m)$, or in terms of $T_1 = l f_t\ (\tfrac{1}{2}(1 + e^{-f\theta})\ T_1)$.

Now neglecting here the comparatively unimportant element of local tension that may be caused by starting a car, and T_1 is the maximum tension, to safely bear which the size of the cable must be designed. As will be more fully considered later the strength of a cable is directly proportional to its cross section, or to its weight per unit of length ; using a general constant to express this proportion, we may say $T_1 = c$ (weight of unit length) $= c\,\frac{\text{cable weight}}{l}$, and substituting this value of T_1 in the above equation, and writing for the product of the different constant terms a general constant c_1, and we have

$$\Sigma f_t\,(T) = c_1 \frac{l\ (\text{cable weight})}{l} = c_1\ (\text{cable weight}),$$

from which, as at first expressed,

$P_3 = f_r$ (cable weight) $+ c_1$ (cable weight) $= K_3$ (cable weight), where K_3 is the sum of the two constant terms f_r and c_1.



Breaking strain in tons.
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Cables
Crucible Cast Steel,
with Hemp centers.
Weight in pounds per foot of cable.

In the above, some small elements of friction have not been considered, as they are thought to be comparatively insignificant, and as their introduction would give a needlessly complex equation. Neglecting these, then, the conditions of this equation may be now stated. For a cable designed to work with a given factor of safety and having an average constant amount of deflection, say one right angle curve per mile, then for all variations either in length or size $P_2 = K_2$ (cable weight), where P_2 is the pull in pounds required to run the cable, without cars, at the given velocity, and K_2 is a constant depending on the type of construction, such as size of sheaves, curvature per mile, etc. Between different types of construction it is, of course, apparent that K_2 will be smaller the less the curvature in the line, also it will be smaller the greater the ratio of diameter of sheave to diameter of journal. It also should be noted that the greater the factor of safety, or, which is the same thing, the smaller the ratio of T_1 to weight of unit length of cable, the smaller will be the value of K_2. So that between roads where not only the type of construction is different, but where the size of the cable is arbitrarily assumed, there is little comparison in the values found for K_2. This is the constant of construction mentioned at the beginning of this paper. Some determination of the separate values of its tension and weight elements and their laws of variation is of decided importance, as will be appreciated further on when we see its effect on efficiency. This determination might be attempted theoretically, but without the guidance of experimental data it would hardly be more than a modified guess, and in this paper I have preferred to rest the matter here. Actual values of K_2 will be considered later.

Our expression for P_2 is now K_2 (cable weight),

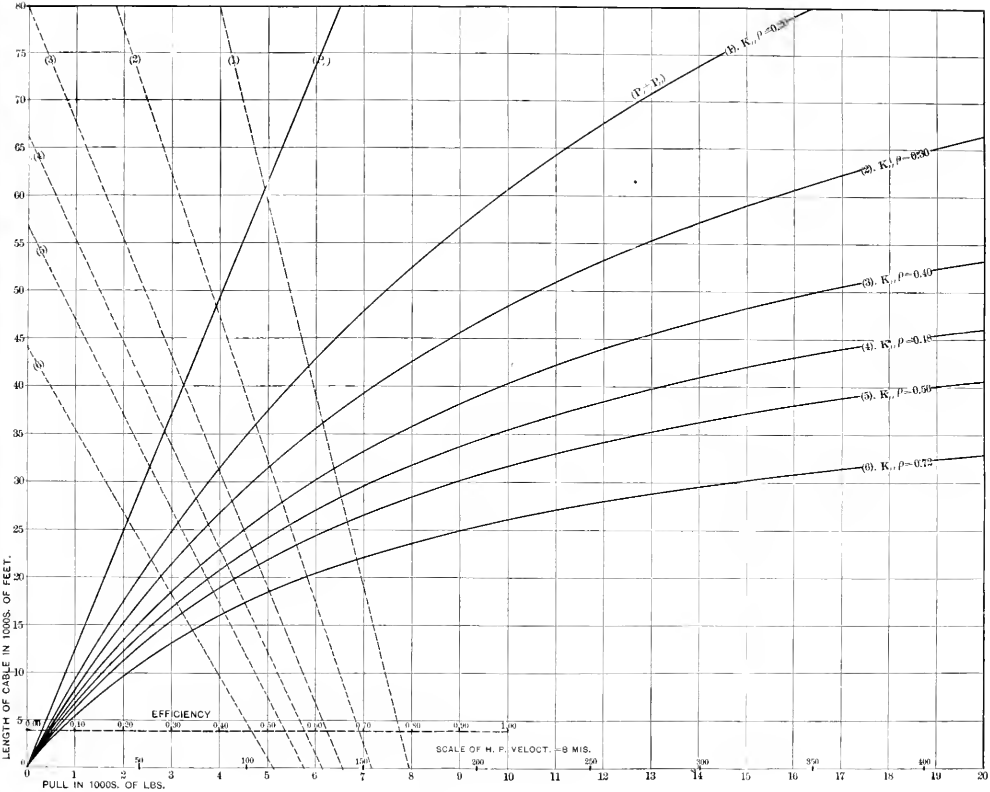
$$\text{or } P_2 = K_2 \text{ (weight per foot)} \times L \qquad (1)$$

where L is the length of cable in feet.

The weight per foot of cable is expressed in terms of the tension the cable is expected to bear from the data on the following diagram. The weight per foot in pounds is there plotted as abscissæ to the breaking strain in tons, as ordinates, for crucible cast steel cables with hemp centres of various makes. The line drawn on the diagram expresses the ratio of strength to weight used. It is about a mean line, and is close to the points (marked △) of Roebling & Sons, 7 strand 49 wire cables. The divergence of some of the points from this line is not so important when we remember that only from $\frac{1}{4}$ to $\frac{1}{8}$ of this breaking strain is taken in practice for safe working loads. This line gives the ratio $\frac{\text{weight per foot in lbs.}}{\text{breaking strain in tons}} = 0.0522$, or introducing a factor of safety "ρ" to pass from breaking to working strain, and substituting for strain the maximum tension in tons T_{mx} that may be thrown on the cable, we have

$$\text{Weight per foot} = 0.0522\,\rho \quad T_{mx}. \qquad (2)$$

At this point it will be necessary to consider again in more detail the ratio between the tensions on the taut and slack side of the driving drum, and their relation to the pull transmitted. The equation has been stated $\frac{T_1}{T_2} = e^{f\theta}$ where f is the co-efficient of friction between the sur



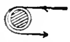
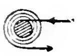
EFFICIENCY OF CABLE ROADS

faces of drum and belt and θ is the angle of contact on the drum. From this follows :

$$T_1 = \frac{e^{f\theta}}{e^{f\theta} - 1} \times P,$$

where P is total pull transmitted, or $T_1 - T_2$, T and P being taken in the same units.

The expression $e^{f\theta}$ may be put in the form $10^{2.7288 f n}$, where n is the number of wraps that the cable makes on the drum. In this form it is easily calculated, being simply the number whose common log. is the exponent of the expression. n on the cable roads is generally made up of a given number of half wraps. For different values of n the ratios above mentioned have the following values. In the calculations f has been taken $= 0.20$, the co-efficient of friction for steel on cast iron (Trautwine).

Turns of cable.	$n =$	$e^{f\theta}$ or $\frac{T_1}{T_2}$	$\frac{e^{f\theta}}{e^{f\theta}-1}$ or $\frac{T_1}{P}$	* Values of φ
	½	1.875	2.24	2.0
	1	3.514	1.40	1.6
	1½	6.586	1.18	1.3
	2	12.364	1.09	1.2
	2½	23.142	1.04	...

$n = \infty$ 1. +

* To be explained.

In the different cable roads that I have been able to learn of, the value of n has varied from ½ wrap to 2½, so that in this general discussion a variable term will be introduced for the ratio $\frac{T_1}{P}$ or $\frac{e^{f\theta}}{e^{f\theta}-1}$. For brevity, this ratio will be designated as φ, and this variable would have intermittent values, as shown in the above tabulation. It must be remembered, however, that these values of φ are for the greatest possible values of P, or where the cable is on the point of slipping on the drum. In practice, therefore, φ should be taken somewhat greater. About actual values for φ are written in the last column. In the first value for ½ turn. φ has been decreased, because it is thought that this arrangement would rarely be used, except for a grooved wheel, in which case f would be decidedly larger. Also beyond 2 turns φ has not been taken, as increasing the wraps beyond this is shown to give but slight advantage. Taking tension in tons and pull in pounds, which are the units that have been previously used, we may write

$$\frac{2{,}000\ T_1}{P} = \varphi, \text{ or } T_1 = \varphi \frac{P}{2{,}000} \qquad (3)$$

where φ, as shown, depends only on the winding of cable on the driving drum, and the economic regulation of the tension on the slack side.

In the special investigation of efficiency, φ will be taken as having the value of 1.2, or where the angle of contact is equal to 2 turns. This

is the value for the St. Louis cable road, the contact there being four half wraps on the driving drum.

Now T_1 is the maximum tension that would be thrown on the cable from the simple operation of driving it so as to transmit a total pull P. But in determining the maximum tension or T_{mx} to which the cable may be subjected, there is another element that must be considered here. It is the extra strain that may be brought on the cable at any point in starting a train. It may be considered as a local strain coming from connecting a stationary with a moving body, and it might approximate the maximum force exerted while starting the train. This strain, taken in tons and called z, will be used as a variable in the general discussion. But first some considerations of the values that it may have may be given, assuming that it equals the maximum force in starting a train. In the paper by Mr. Wright, before referred to, he found, on horse roads, forces as great as 283.5 pounds. per ton in starting cars. This would give for a 12-ton train a value for z of about 1.7. It should be remembered, however, that on horse lines the value found is limited by the pull that the horses can exert, while in cable lines it is limited by the way the gripman puts the pressure on the grip. Every one who has stood on a cable car behind a new gripman has felt this force, which at times he could hardly stand against, and if we consider that this force is multiplied by every passenger in the car and also the dead weight of the car and grip, and that the cable may be locally strained by about that amount, some personal idea of the value of z may be realized. In passing, I might state that Mr. Wright's value of 283.5 per ton is about equal to a pull of the kind described of 20 pounds on the average passenger.

It is probable that on cable roads this force is somewhat greater than the value 283.5 per ton. This as the value for f_c before mentioned, or resistance per ton to traction, could so easily be determined together that there is no necessity for any closer assumption of it in this paper. z must enter as a variable in the general equation, since only its value per ton may approach constancy, and there is no objection to regarding its limits of variation extended somewhat so as to include possible future more accurate determinations of its constant element; about the practical limits of z would probably be from 1 to 3, or from an 8-ton train at 250 pounds strain per ton to a 14-ton train at 430 pounds per ton. The value of z taken in the special investigation will be 2, or for the 12-ton train already assumed, a local strain of 333 pounds per ton.

We now have the equation

$$T_{mx} = T_1 + z. \tag{4}$$

Bringing together now equations (1), (2), (3) and (4), that have been explained in some detail.

$$P_2 = K_2 \text{ (weight per foot) } L \tag{1}$$

$$\text{(Weight per foot)} = 0.0522\ \rho\ T_{mx} \tag{2}$$

$$T_1 = \varphi \frac{P}{2{,}000} \tag{3}$$

$$\text{and} \quad T_{mx} = T_1 + z \tag{4}$$

And making the apparent substitutions,

$$P_2 = K_2\ L\ 0.0522\ \rho \left(\varphi \frac{P}{2{,}000} + z \right)$$

and remembering that $P = P_1 + P_2 = K_1 L + P_2$

$$P_2 = K_2 L\, 0.0522\, \psi \left(\varphi \frac{K_1 L + P_2}{2,000} + z \right)$$

Or,

$$P_2 \left(1 - \frac{K_2\, 0.0522\, \rho\, \varphi\, L}{2,000} \right) = \frac{K_2\, 0.0522\, \rho\, \varphi\, K_1\, L^2}{2,000} + K_2\, 0.0522\, \rho\, z\, L$$

Or, taking L in units of 1,000 feet, instead of in units of one foot, as in the above expression, and we have finally,

$$P_2 = \frac{26.1\, K_1\, K_2\, \rho\, \varphi\, L^2 + 52.2\, K_2\, \rho\, z\, L}{1 - 0.0261\, K_2\, \rho\, \varphi\, L} \qquad \text{(II)}$$

A glance at this equation shows the theoretic limit to the length of a given cable road which was mentioned at the beginning of this paper. Where the last term in the denominator equals one, the denominator becomes zero, and hence P_2 infinite, or this may be stated practically as follows: A cable road of that given type of construction could not be run beyond that length without working the cable with a smaller factor of safety than the one chosen. Of course no one would work it close up to this length, since its best possible efficiency would be then next to nothing.

Tho only quantity in this expression for P_2 that we may not now assign reasonably close values to, in a given case, is K_2, this may be called the co-efficient of cable friction, or the pull in fractions of a pound required to move at the given velocity one pound of cable. Without actual data from roads that have been constructed, very little idea of the value of K_2 could be formed. For my own part, when I first commenced investigating the subject I was decidedly surprised at the magnitude of some of the values found for it, as well as the large variation that it underwent for different roads. In what follows I give all the actual data that I have been able to collect so far on this subject. It is needless to say that this list could have been much enlarged from various sources, if estimates of H. P. had been accepted, but I have preferred to present only those cases where the H. P. was determined by indicator diagrams, and thus an accurate determination of K_2 made.

The data for the following determinations of K_2 on the San Francisco cable roads is taken from a paper by W. W. Hanscom, M. E., in the *Street Railway Gazette*, 1886, Nos. 6–9.

SAN FRANCISCO CABLE ROADS.

Name of road.	Length of cable in feet.	Total weight of cable in lbs.	Speed of cable in miles per hour.	Total H. P. to pull cable without cars.	Deduced K_2 or pull in lbs. per lb. of cable.
Clay	11,000	15,400	6	22.6	0.0917
California	25,895	65,000	6	84.0	0.0808
Union	21,000	30,500	6	39.0	0.0799
Market, Valencia & Haight	65,765	164,412	8	201.0	0.0573
McAllister	27,183	68,000	8	60.0	0.0414

Such details of these roads as could be found may be seen by consulting the paper above referred to. They were not sufficiently full to justify an attempt to discuss the specific causes of this variation of K_2. It may be stated generally that Clay, California and Union are steep-grade

lines, at times about 1 to 6, crossing level streets, involving a number of depression pulleys. Also that Market, Valencia and Haight is described as if it were composed of three separate cables run from one engine.

The following is the data of the St. Louis cable road:

Length of cable in feet.	Total weight of cable in lbs.	Speed of cable in miles per hour.	Total H. P. to pull cable without cars.	Deduced K_2, or pull in lbs. per lb. of cable.
35,700	89,250	8.	178.5	0.094

The following are the main details of the construction: The line is operated as one cable from power station about ¾ mile from its western terminus; sheaves on line 10 inches diameter, spaced 32 feet apart; on curves, an 18-inch sheave at each tangent point and filled in between these about as close as can be spaced, 15-inch sheaves on curves of small radius, and on those of larger radius 13 inch sheaves; at ends, elevation sheaves 40 inches, turn drums, 9 feet; diameter of driving drum, 10 feet. The cable makes four half wraps on this drum. The minimum tension on slack side at time of determining the horse-power given above was 1.2 tons.

The road is a double line throughout, making in all 14 turns, or 28 single curves, around which the cable passes, 4 of these 14 turns are through right angles, the others are through various deflections from about 60 degrees down.

For the following data of the Kansas City cable road I am indebted to Clift Wise, C. E., Chief Engineer of that road:

The road is a double line throughout, driven at present from one power station near its western terminus. Near its eastern terminus the main cable passes around two pulleys, giving power to these to run a short auxiliary branch.

	Length of cable in feet.	Total weight of cable in lbs.	Speed of cable in miles per hour.	Total H. P. to pull cable without cars.	Deduced K_2, or pull in lbs. per lb. of cable.
Main cable ..	29400	88,000	7.1	114	0.068
Auxl. " ..	5800				

The main details of construction are: terminal sheaves and drums, 12 feet diameter; sheaves on curves, 2 feet 10 inches; carrying sheaves, 2 feet; on auxiliary cable, carrying sheaves, 1 foot; 10 sets of depression sheaves on the line, diameter 5 inches; 5 right angle curves in the double line.

The variations of all the terms entering the general formula for P_2 have been now considered, and about the limits of the variation and the special causes producing it have been considered in each case, with the exception of the co-efficient of cable friction, or K_2; for this, on roads for which reliable data could be found, the data and the determination of K_2 have been given. We may, therefore, close the general discussion with the equation for efficiency E, as follows, $E = \dfrac{P_1}{P_1 + P_2}$.

This may be written out from the formula given for P_2 and P_2, but its characteristics will be apparent in the special consideration that follows.

If other engineers are anything like myself, very shadowy ideas are all that are gotten by looking at a general formula, I have, therefore, taken about mean values for all the elements except the three, viz., length of line L, factor of safety in cable ρ, and co-efficient of cable friction K_2,

the effect of whose variation, as stated at the beginning, was the special object of this paper. From now on I will in the main consider quantities and not equations.

Taking these mean values, or

$K_1 = 0.0812$, approximate for a 3 minute service on 8 miles velocity of cable with average weight of train 12 tons.

$\varphi = 1.2$, ratio of tension on driving side of drum to pull transmitted about safe for 2 wraps of cable on drum.

$z = 2.0$, local strain in starting a car, or 12 tons by 333 pounds per ton.

And we have

$$P_1 = 81.2\, L.$$

$$P_2 = \frac{2.5432\,(K_2\,\rho)\,L^2 + 104.4\,(K_2\,\rho)\,L.}{1 - 0.03132\,(K_2\,\rho)\,L}$$

where L is taken in units of 1,000 feet, and in this equation values will be assumed for $(K_2\,\rho)$, covering about all the possible range in the product of these two quantities and for each assumed value of $(K_2\,\rho)$, the car pull, the cable pull, the total pull, and the efficiency will be determined for the different values of length of road up to 80,000 feet, or up to 20,000 pounds pull (a little over 400 horse-power on an 8-mile velocity).

A word first in regard to the nature of the product $(K_2\,\rho)$. It has been already pointed out that there is in part some reciprocal variations between the elements, that while an increase in ρ would increase their product, yet it would not increase as an exact multiple, for its increase would involve a decrease in the tension element of K_2, the friction per unit weight of cable, due to tension, being less the smaller the tension per unit weight, or the greater the factor of safety. It is hardly probable therefore that the extreme values that will be taken for this product in what follows are possible in reality. For instance, on the McAllister road $K_2 = 0.041$, its factor of safety is over 10, though not exactly known from the data; the extreme in this direction will be taken as $(K_2\,\rho) = 0.04 \times 5 = 0.20$, the other extreme will be taken as $0.09 \times 8 = 0.72$.

The values taken for this product are

$$\begin{aligned}(K_2\,) = 0.20 \quad &(1)\\ 0.30 \quad &(2)\\ 0.40 \quad &(3)\\ 0.48 \quad &(4)\\ 0.56 \quad &(5)\\ 0.72 \quad &(6)\end{aligned}$$

Probably all actual values would be found between 0.30 and 0.56.

In the place of a tabulation of these values I have substituted a diagram as best illustrating the nature of the variation, and it must be remembered that this is all that is here aimed at, for each road would have special values of K_1, φ and z, probably differing from those here assumed.

On this diagram, length (L) is taken as ordinates, and pull (P) as abscissæ. The car pull is there plotted for different lengths, giving the straight line marked P_1. The total pull, or $P_1 + P_2$ is plotted for the different lengths for the six values assumed for $K_2\,\rho$, giving the six curves marked (1)—(6) with the value of $K_2\,\rho$, with which each is calculated. The distance in the direction of pull between the line of car

pull and the curve of total pull gives in each case the value of cable pull for that case. For the sake of easy comparison, a scale of H. P. equal to any given pull on a cable moving at a velocity of 8 miles per hour is placed above the scale of pull.

For efficiency, its value, like pull, is taken as abscissæ, to length as ordinates; for clearness the scale and lines of efficiency are drawn as broken lines. This efficiency $\left(\frac{\text{car pull}}{\text{total pull}}\right)$ is determined for each of the six different curves of total pull, and its value in each case for different lengths, plotted; giving the six broken lines marked (1)—(6). These lines correspond to the curves of total pull marked with the same number, and each one gives the variation of efficiency with length in that case, while their different positions show the difference in efficiency and its variation with length resulting from different values of $K_2 \rho$. The importance of this element may be now seen; for example, assuming as before the probable actual limits to this product $K_2 \rho$ of 0.30 and 0.56, these values, on a road designed for the service here treated of, and cable 35,000 feet long, would represent efficiencies of respectively $48\frac{1}{2}$ and $22\frac{1}{2}$ per cent., or more than double the power to operate the one than the other.

Before closing I wish to point out a method for making all the calculations needed in an investigation of any special case, much more simply than the direct one which has been followed in this paper for the sake of its logical order. It is seen that the variation of efficiency with length is in each case on a straight line. This might have been easily deduced from the general equation, which by simple reduction becomes, in its most general form:

$$E = \frac{1000\ K_1\ (1 - 0.0261\ K_2\ \rho\ \varphi\ L)}{1000\ K_1 + 52.2\ K_2\ \rho\ z} \qquad \text{(III.)}$$

K_1 being thus determined by the traffic for which the road is built, φ by the arrangement of cable on driving drum, and z, by the starting strain of a loaded train, we may, from the curvature and general plan of the road, assume moderately narrow limits between which the actual values of $K_2\ \rho$ would be found. Two points in the efficiency line for each of these values would then graphically determine two lines between which the actual efficiency would be found at any length, and the H. P. required to operate any length would lie between the two values obtained by dividing the H. P. corresponding to car pull there, by the two limits of efficiency at that length.

In default of any personal knowledge by which we may expect to fix reasonably close limits in a given case to this value $K_2\ \rho$ we may probably, with moderate approximation for cables beyond 20,000 feet in length, and for a fairly heavy traffic carried in trains, determine the efficiency by assuming an initial value of 75 per cent. for fair construction, and from this initial value subtracting $3\frac{1}{2}$ per cent. for every half mile of double track road, and $3\frac{1}{2}$ per cent. for every right angle curve of the double line, or for every two right angle curves of a single line, curves less than a right angle being given a value equal to ($3\frac{1}{2}$. versin $\angle$) where $\angle$ is the total angle of deflection at any curve.

In the above, the equivalence of a right angle curve to a half-mile of line comes to me second hand from Mr. Robt. Gillam, former Chief

Engineer of the Kansas City Cable road. I do not know on what experimental data it rests ; the rest of the statement depends on a mixture of theory easily followed in examining the general equation of efficiency, and on assumption that $K_2 \rho = 0.30$ is about a correct mean value for fair construction and straight road.

I wish it to be recognized that I make this last statement in regard to an approximate determination of efficiency with a *very mild* emphasis. I have found it convenient in my own case, as giving a definiteness to thought on the subject, and a rapid method of at once mentally approximating the effect of different locations of power stations, and I therefore simply give it for what it may prove itself to be worth.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

FEBRUARY 16, 1887:—A regular meeting of the Boston Society of Civil Engineers was held and called to order at 7:45 P. M., President George L. Vose in the chair, thirty-six Members two visitors present.

The record of the last meeting was read and approved.

Messrs. E. H. Lincoln, Chas. Mills and J. E. Stone were elected Members of this Society.

Mr. C. H. Benjamin was proposed for membership, recommended by M. M. Tidd, F. C. Coffin.

On motion, it was voted : That Mr. Henry Manley be appointed a committee to arrange for the annual dinner, and that the sum of fifty dollars be appropriated for the general expenses of the dinner and placed at the disposal of the Committee.

On motion, it was voted : That a committee of three be chosen by nomination at large to prepare a list of candidates for officers of the Society for the year 1887, and that the Committee be instructed to present three names for each office. The Committee as appointed consists of Fred Brooks, W. E. McClintock, D. Fitz Gerald.

On motion of Mr. Henry Manley, it was voted: That Article XV. of the Constitution be amended by substituting the word thirty for the word fifty in the second line thereof. Adopted. Affirmative, thirty-one; negative, zero.

Professor George L. Vose addressed the society on the subject of Defective Roofs: The Cause and Remedy.

Attention was first called to the fact that one can hardly take up a newspaper without finding an account of some roof which has collapsed, with more or less serious results. The cause of these disasters, accidents they were' not, was very easily found in the wilful or ignorant neglect of a very few very simple rules. Many roofs were put together in utter disregard of all the laws of stability and strength, by persons who either did not know or did not care what they were doing. Other roofs, though planned and carried out under the direction of men who are considered to be good architects, were shown to be defective both in design and in the amount of material employed. Reference was made to flagrant violations of the laws in Boston governing the inspection of buildings, in which city roofs of the most defective and dangerous character were allowed to be erected and used, even in buildings of a public character, which were often filled with large crowds. Attention was called to the fact that many roofs, while good in general design and having ample material, were yet entirely unsafe on account of bad details. The effect of temperature upon roofs of wood and iron combined was referred to, and examples shown where the design was such as to bring large and quite indeterminate strains upon the material from this cause. Cases were cited showing the violent action of wind and the accumulated forces from wind and snow under certain conditions, and suggestions were made as to the proper method of introducing these factors in computations for roof trusses. Illustrations were given of defective roofs of various forms, some of which had already fallen, while others remained standing only under the

most dangerous condition. Roofs were referred to which had been pronounced safe by architects and inspectors, where the least possible allowance for wind and snow would strain the iron tie-rods more than 20,000 pounds per square inch. Attention was called to the fact that in many cases the iron rods put into roofs were bought by the carpenter or contractor at the hardware store, and were of a quality of which no person had any knowledge whatever. In conclusion, it was recommended that in the design of trussed roofs only such simple forms should be employed as could be made a matter of exact calculation; that good material, and plenty of it, should be put into all roofs; and that especial care should be taken in the study of the details, and in seeing that the plan was correctly carried out. A small amount of technical knowledge, faithfully applied, it was stated, would have prevented all of the disasters of this kind that have ever occurred.

The Secretary presented for Mr. Thomas Appleton a paper entitled "Some Notes on Municipal Public Works." This paper treats of the methods of defraying the expense and assessing the cost of public improvements in some cities in the West.

[*Adjourned.*] H. L. EATON, Secretary.

ANNUAL MEETING.

MARCH 16, 1887:—The Annual Meeting of the Boston Society of Civil Engineers was held at Young's Hotel, Boston, Wednesday, March 16, 1887, at 7:30 P. M., Mr. Thomas Doane in the chair, sixty-seven Members and eight visitors present. The record of the last meeting was read and approved.

Mr. C. H. Benjamin was elected a Member of this Society.

Messrs. John C. Olmstead and Simpson C. Heald were proposed for membership, recommended respectively by A. H. French, E. W. Howe; Henry Manley and E. L. Brown.

Mr. Thomas Doane presented and read a memoir of Theophilus E. Sickles, an Honorary Member, and Mr. Clarence W. Lunt, an Active Member of this Society. Mr. William Watson addressed the Society, alluding to the life and character of Mr. Sickles and his great attainments in canal and railroad engineering. President Vose also referred to his high standing as civil engineer.

On motion it was voted: That these memorials be accepted and printed with the Transactions of the Society.

The amendment to the Constitution, Article XV., proposed in writing and passed by a vote of thirty-one to zero, at the last regular meeting, was adopted by a vote of forty to zero.

The annual report of the Government was read by the Secretary. It was ordered to be printed with the Proceedings of the Society.

The Treasurer presented his annual report, approved by the Auditor. It was voted that the Treasurer's report be printed with the Proceedings of the Society.

The Treasurer moved that the sum of two hundred dollars be transferred from the permanent fund and devoted to the current expenses of the Society. Mr. D. Fitz Gerald moved to amend, that the question be referred to the next meeting. The amendment was accepted and the motion as amended passed.

On motion of Mr. F. P. Stearns it was voted : That an assessment of six dollars be levied on resident Members of the Society.

The Committee on Weights and Measures presented its annual report.

On motion it was voted : That the reading of this report be postponed until the next meeting.

President Vose, of the Special Committee on Preservation of Timber, presented a verbal report.

Mr. Desmond Fitz Gerald presented and read the annual report of the Special Committee on National Public Works.

Mr. Dexter Brackett, of the Special Committee on Excursion, presented a verbal report.

Mr. Henry D. Woods presented and read the annual report of the Special Committee on Library. The report of the Committee was accepted and its recommendation adopted.

On motion it was voted : That the reports of the special committees be accepted and printed with the Proceedings of the Society.

The Committee appointed at the last meeting to present a list of candidates for officers of the Society for the ensuing year presented the following report:

For *President*—E. C. Clarke, C. Herschel, L. F. Rice.

For *Vice-President*—C. W. Folsom, F. P. Stearns, M. M. Tidd.

For *Secretary*—E. P. Adams, H. L. Eaton, F. W. Hodgdon.

For *Treasurer*—H. Bissell, H. A. Carson, H. Manley.

For *Librarian*—G. W. Blodgett, A. E. Burton, H. D. Woods.

Respectfully submitted.

FRED BROOKS,
W. E. MCCLINTOCK, Committeee.
D. FITZ GERALD,

The report of this Committee was accepted and the Committee discharged.

The Society then proceeded to ballot for officers, with the following result :

President, L. Fred. Rice.

Vice-President, Fred. P. Stearns (third ballot).

Secretary, Horace L. Eaton.

Treasurer, Henry Manley.

Librarian, Henry D. Woods.

Mr. Thomas Aspinwall was elected Auditor by vote.

On motion, it was voted that the matter of appointing the special committees be referred to the Government, with full powers.

[*Adjourned.*] H. L. EATON, Secretary.

ANNUAL REPORT OF THE GOVERNMENT OF THE BOSTON SOCIETY OF CIVIL ENGINEERS, MARCH 16, 1887.

The past year has been a prosperous one for the Boston Society of Civil Engineers. Our membership has been largely increased, the meetings have been well attended, and numerous valuable papers and discussions have occupied the sessions. A particularly important feature during the past year has been the excursions, which have been made to various points of engineering interest. The trips to the Stony Brook Dam, Cambridge Water-Works, to the Troy & Greenfield Railroad and Hoosac Tunnel, to the Cohasset Water-Works and to the Meiggs Elevated Railroad, have been the means not only of social enjoyment, but of a very profitable interchange of opinion upon engineering matters. It is to be hoped that these excursions will continue to be a prominent part of the work of the Society. A course of four lectures on "First Aid to the Injured" has been given before Members of the Society by Dr. Robert W. Greenleaf. These lectures were given under the direction of the Massachusetts Emergency Association, were well attended and have been of great interest and value.

Our membership stands at present as follows : Honorary Members, 6 ; Corresponding Member, 1 ; Active Members, 177 ; total membership, 184. When the membership exceeded 150, the Society became entitled to an additional representative upon the Board of Managers of the Association of Engineering Societies, and Prof. W. S. Chaplin was elected as our additional member of that Board. During the past year the Society has lost by death two of its members, E. S. Chesbrough and Prof. William R. Nichols. In the loss of Mr. Chesbrough there is broken another link in the chain which connects us with the early civil engineering of the country, and in his death we have lost not only an engineer most eminent in the profession, but a man, in the fullest sense of the term. In Professor Nichols we have lost one of the foremost men of science in the country, and one who has been especially serviceable in making pure science of use to

the engineer. We may well say in regard to Professor Nichols that the better he was known the more fully was he appreciated.

The number of Members admitted during the past year has been 34. This rapid growth is a favorable sign, so long as those who are admitted are able and willing to take a part in forwarding the objects of the association. But it is evident that there must be no relaxation in the care with which applications for membership are scrutinized, or the gain will be in quantity only, and not in quality.

The average attendance at our meetings has been during the past year about 20 per cent of the active membership. The whole number of essays presented has been 19, or about one paper for each 9 Active Members. This does not seem to be a very large number. If each one of our Active Members would present a paper once in five years we should have nearly double the number of contributions that we do at present. In referring thus to the work of the year, the Government does not mean to infer that we are behind the general run of societies in this matter, nor does it wish to underrate the value of the time spent in the discussions that follow the more formal papers. Are we then as a society doing as much as we should to collect, arrange and digest the results of the current engineering practice

Our library is steadily increasing, and in the hands of Mr. H. D. Woods is being so arranged as to be easy of access. We have now in all nearly 1000 books and pamphlets, and among them a large amount of valuable periodical engineering literature. The room, too, in which the books are now placed affords an opportunity to members to consult them at all times during the day. The Government would suggest, in this connection, the desirability of collecting photographs and blue prints of engineering works. It would be an easy thing for each Member to send a blue print of any construction on which he may be engaged to the Society. This in time would result in a large accumulation of valuable material.

During the past year Article XV. of the Constitution was amended, so as to increase the non-resident fee from three to four dollars per annum ; and By-Law No. 12 was added, fixing the salary of the Secretary at $100 a year. This was eminently proper, as the duties of the Secretary are now very considerable.

In conclusion the Government congratulates the Society upon its present standing. A continuation of the active interest which has been shown by the Members cannot fail to be of value to each and to all. Respectfully submitted,

George L. Vose, President.
L. Frederick Rice, Vice-President.
Horace L. Eaton, Secretary.
Henry Manley, Treasurer.
Henry D. Woods, Librarian.

ABSTRACT OF TREASURER'S REPORT FOR THE FINANCIAL YEAR, 1886-87.

Current Fund—Receipts.

Non-resident dues for current year, 13 Members at $3	$39.00
Non-resident dues for coming year, 26 Members at $4	104.00
Assessment levied March 17, 1886. 115 Members at $6	690.00
Assessment of 1885, 2 Members at $6	12 00
Interest, Proceedings sold, Journal to New Members	25.33
Cash on hand, March 14, 1886	89.50
	$959.83

Receipts—Permanent Fund.

Entrance fees	$332.00
Interest on bonds	86 00
Cash on hand, March 17, 1886	559.19
	$977.19

Permanent Fund—Expenditure.

Book-cases	$80.63
Balance, cash on deposit, March 10, 1887	$896.56

Current Fund—Expenditures.

Association of Engineering Societies	$506.25
Binding and library supplies	59.72
Periodicals	36.93
Printing notices, records, list of Members	141.15
Postage, stationery, etc	83.92
Secretary's salary	12.50
Annual dinner	33.50
Janitor	24.00
	$897.97
Balance, cash on hand March 10, 1887	61.86
	$959.83

Schedule of the Property of the Society in the hands of the Treasurer, March 10, 1887.

One Republican Valley R R. Co. 6 per cent. bond	$600.00
One Atchison. Topeka & Santa Fe "plain 5"	1,000.00
Permanent fund, cash	896.56
Current fund, cash	61.86
	$2,558.42
Less unpaid bill	100.00
	$2,458.42
Schedule at last annual meeting	2,248.69
	$209.73

HENRY MANLEY, Treasurer.

REPORT OF COMMITTEE ON NATIONAL PUBLIC WORKS.

BOSTON, March 16, 1887.

To the Boston Society of Civil Engineers :

The undersigned, members of the Committee on National Public Works, submit herewith their report for the past official year.

In April, 1886, several matters relating to the policy, membership and financial status of the Council of Engineering Societies on National Public Works were referred to various sub-committees to report.

The part taken by the Boston Society on the question of national public works has always been somewhat conservative, and as no particular branch of the subject was referred to your Committee, they simply waited for further developments, in the meantime endeavoring to post themselves as much as possible on the questions likely to arise.

In January last your Committee received a letter from the Secretary of the Council asking for suggestions, and in reply thereto your Committee, after full conference on the subject, sent a letter suggesting that for certain reasons the plan for action already adopted be abandoned so far as it involved the different engineering societies, and an effort be made to form an organization outside of the societies. This idea is now being considered by the General Council, but no definite answer has yet been received by your Committee. It is anticipated, however, that a general call will be issued before the first of April, and your Committee a day or two since received the following communication.

THE EXECUTIVE BOARD OF THE COUNCIL OF ENGINEERING SOCIETIES ON NATIONAL PUBLIC WORKS.
CLEVELAND, O., March 11, 1887.

Desmond Fitz Gerald, Chairman Com. Nat. Public Works, Brookline, Mass.

DEAR SIR : Your favor of the 3d was handed me on my return to the office, and in reply would say that the result of my last correspondence shows that the various sub-committees appointed to gather and compile the desired information are not ready to make their final reports. However, it is expected to have it prepared and submitted some time early in the summer, and, if possible, to complete the final report of the Ex. Brd. for the use of Congress some time in October. Under the circumstances we are asking the various clubs to continue their committees at least until the next call of the General Council. Will keep you advised as to the time.

Very respectfully,
JOHN EISENMANN, Sec. and Treas.

P. S.—The circular for a call will probably be out on or before April 1.

DESMOND FITZ GERALD, Chairman.
WM. E. MCCLINTOCK.
SIDNEY SMITH.

REPORT OF THE LIBRARY COMMITTEE.

To the President and Members of the Boston Society of Civil Eng.:

The Committee appointed last year to look after the welfare of the Society's library would submit the following report :

After considering different methods of fostering the growth of the Society's library, it was decided that each Member should look out for such documents and literature, suited to the object of the library, in some particular branch, so as not to conflict with each other. Suitable blank forms were printed, to be filled out with the name of the special document required, and these are sent in the name of the Society to parties who are supposed to have books or reports which are desirable. In this way some 200 books or papers have been added to the shelves, comprising Municipal, State, and General Government Reports, Specifications, Descriptions of Works, Tests, etc.; Society Publications, etc. Whenever a Member sees or hears of a desirable report of a certain class he sends a request for it, and, as a rule, they have been promptly filled.

The library also receives regularly all the publications of the U. S. Coast Survey Geological Survey, Smithsonian Institute ; Chief of Engineer's Rep., the proceedings and transactions of some 12 or 14 engineering societies, including the Institute of C. E. of Great Britain and the Liverpool Engineering Society. Arrangements have just been made for an exchange of publications with the French Society of C. E. The reports of the State Board of Health of Illinois, New York, and Rhode Island have also been obtained recently. The Society also takes 5 weekly journals and 2 monthly periodicals.

In this way some 300 numbers have been added to the accession book this last year, making a total of some 1000 numbers : of these 260 volumes of bound periodicals, 180 bound books and reports, and some 560 papers, specifications, etc.

During the past year a full list of the publications on the shelves have been regularly entered in a permanent accession book, which gives full record of each book, and being bound in permanent form can be filed away when filled, and a second, third, etc., volume of the same kind can be procured.

An alphabetical list by authors has been made out on separate sheets, with loose binder, so as to be easily added to.

Some 800 cards have been prepared for a card catalogue, covering about five-sixths of the publications. They have been arranged in dictionary form for the present, as being more easily understood.

As yet no method of shelf numbers has been undertaken, except so far as numbering each shelf by itself. But the records are kept in such a way that when a system is adopted it can quickly be inserted.

The library is accessible to members on week days during the usual business hours. The keys are to be found at the office of Mr. Blodgett, the electrician of the B. & A. R. R., on the same floor as the rooms. Members are simple requested to lock the doors and return the keys to their place on leaving the rooms.

It may be well at this time to suggest that Members who receive the Society's periodicals should arrange to send them to the rooms at least the day of meetings, so that others may have access to the current literature of the Society.

Some Members have suggested that if more shelf room was obtained they would like to place some of their books on the Society's shelves. Considering that the Society has not the exclusive use of the room it occupies, and that the meetings of the other society are usually much more attended, it does not seem advisable to take up any more space for book cases. But if Members will send in their books, many of those now on the shelves can be laid aside in the old cases, as they are never consulted, and plenty of room can be thus made for their books.

It has been suggested that the A. S. C. E. publish each month a list of the additions to the library at the end of their monthly reports. It is recommended that some such measure be carried out here. A list of the principal publications in the

library has been prepared, and may be added to the next printed list of Members as an appendix.

Members who have duplicate reports and engineering documents are urged to bring them forward, and thus help increase the usefulness of the library.

Respectfully submitted for the Committee, H. D. Woods, Chairman.

ANNUAL DINNER.

The fifth annual dinner of the Boston Society of Civil Engineers was held at Young's Hotel, Boston, at 6.30 P. M. Professor George L. Vose presided, with 73 Members and 12 visitors present. There were present as guests of the Society W. P. Shinn, Vice-President of the N. Y. & N. E. Railroad; Samuel M. Gray, City Engineer, Providence, R. I.; Dr. Robert W. Greenleaf, of Boston.

After the dinner had been attended to Professor Vose read letters of regret from J. P. Davis, Major G. A. Gillespie, Samuel Nott and A. A. Folsom, and introduced Mr. W. P. Shinn, Vice-President of the New York & New England Rail road, who discussed the Inter-State Commerce bill.

The speaker referred to the wide interpretation which might be given the bill, and stated the object or purpose of the law to be to prevent unjust discrimination. Many complaints of unjust discrimination have been made, which on investigation have proved to have originated with newspapers. The answer to the question, What is the object or purpose of the law ? was decided to be outside the domain of science. Allusion was made to the several sections relating to just and reasonable rates, consequential damages, discriminations by railroads in favor or against persons or localities, the long and short haul clause, the publication of rates, the enforcement of the law. The effect of the law will be to raise rates, increase competition, curtail privileges now enjoyed by merchants and shippers, abolish free passes except to employés, forbid pooling. In the opinion of the speaker nothing has been accomplished in the last twenty-five years in railway management which has done so much good as pooling. It is better to have rates reasonable than low A railroad cannot be expected to carry freight at a loss. Young engineers were advised not to guess, nor to express an opinion not based on information.

Mr. Samuel W. Gray responded to the call for the City Engineer of Providence, and expressed his satisfaction in being able to attend the annual dinner as a guest of the Society.

Mr. E. D. Leavitt, Jr., referred to the relation between mechanical and civil engineers. All professions are being divided into specialties. This fact suggests that we should endeavor to find that detail of the profession to which we are best adapted, stick to that, and call on specialists outside of our branch when needed.

Mr. Clemens Herschel referred to the opposite side of the Inter-State Commerce bill. The long and short-haul law has been established many years in Massachusetts and has worked well. The rate per mile has nothing to do with the case.

Mr. E. C. Clarke referred to the fact that so many engineers are leaving the profession and taking leading positions outside of the profession, and command higher salaries. He differed from the speaker who advised engineers not to guess, being of the opinion that estimating is somewhat close to guessing, especially in estimating for public works, as regards labor and materials, population, water supply, and sewage. The speaker advised guessing as little as possible.

Dr. Robert W. Greenleaf gave a concise history of the work of the Emergency Association in Boston.

Mr. Desmond Fitz Gerald referred to the early history of the Society, the growth of the profession in the past and in the quality of work, the improvement in the quality of engineering papers, the advantage of mutually upholding one another. The advance which engineers gain in taking positions outside the profession is broadening it, and will be a gain in the end.

Mr. M. M. Tidd referred to earlier engineering work, particularly the Middle-

sex Canal, the change from transportation by canal to that by railroads, and the possible improvements to be made in the motive power to be used in propelling trains in the future.

Mr. F. P. Stearns defined the work of the Massachusetts State Board of Health.

Mr. W. E. McClintock described a system of small pipe sewers as planned for the city of Chelsea. The owners of certain patents claim the use of pipe sewers as planned in the system described to be in violation of their patents. The case of these patentees against the city of Chelsea is now being tried. The speaker described some experiments made to obtain the velocities and direction of air currents in certain sewers, the effect on house drains of flushing in sewers; the direction of air currents in sewers was stated to be in an opposite direction to the current. These pipe sewers have remained clean after four years use.

Mr. Henry Manley alluded to the benefits derived from membership in the Society, and the pleasant excursions made during the past season. The younger Members were urged to present to the Society some account of their work.

H. L. Eaton, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

January 5, 1887:—Club met at 8:15 p. m., at Mercantile Library, Vice-President Holman in the chair, fifteen Members and two visitors present.

The minutes of the meetings of December 15th and December 21st were read and approved.

The Executive Committee reported the doings of its meeting of December 21st, announcing the resignation of P. W. Schaumleffel, and recommending the reinstatement of Wm. T. Angell on the rolls of the Club.

The Club then voted to reinstate Mr. Angell.

The Committee on Relations with the Mercantile Library was continued.

The Committee on Resolutions on the death of Col. C. Shaler Smith made a report in the shape of a short memoir, as follows:

By the death of C. Shaler Smith, the Engineers' Club of St. Louis loses a valuable member; the profession of engineering one who had attained the foremost rank and who still gave promise of great things; the material interests of the country, and we may say of the continent, one who did much to overcome natural barriers to commerce and render intercourse and exchange easy; a large circle of personal friends a genial companion, pure in thought, word and life, and his family a husband, father and brother, who tenderly loved and diligently cared for his own.

It is therefore appropriate that we, as a Club, should express our appreciation of the man and engineer who lived and wrought in our midst, our sorrow that he no longer may move among us, and our sympathy with his afflicted family.

While we as a Club mourn the loss of our associate, we point to his works and say, well done; to his influence, and say, it shall live; for his works stand and perpetuate the name of their designer and builder, and among his best works we place the men he has trained and fitted to continue what he so well began. Hence in no strained sense, C. Shaler Smith, the ideal engineer, still lives.

On motion, the report was adopted as expressing the sentiment of the Club, and it was ordered that an engrossed copy be prepared and forwarded to the family.

The Secretary read a letter expressing the thanks of Col. Smith's family for the tribute of sympathy and respect tendered by the Club.

Prof. Johnson stated for Prof. Pritchett that the latter was unable to be present, and, as a change of meeting place was to be made, suggested Washington University, adding that his paper on "Results of Mexican Longitude Determinations" could be presented there to better advantage, and would be ready for the next

meeting. On motion, the Club voted that when it adjourns it adjourn to meet in two weeks in the directors' room at Washington University.

The special order of the day, a paper by T. T. Johnston, on "The Great Water-Way to connect Lake Michigan with the Mississippi River, and its influence on floods in the Illinois River," was then read by the Secretary. It was discussed by Messrs. R. E. McMath, J. A. Seddon, Holman and Ockerson.

[*Adjourned.*] WM. H. BRYAN, Secretary.

JANUARY 19, 1887:—The Club met at Washington University at 8:10 P. M., President Potter in the chair and twenty-six Members and six visitors present. The minutes of meeting of January 5 were read and approved. The Executive Committee reported the doings of its meeting on January 17. The following applications for membership were announced and referred to the Executive Committee: Arthur J. Frith, indorsed by J. A. Seddon and F. E. Nipher; Chas. H. Ledlie, indorsed by F. H. Pond and T. J. Whitman; Edward K. Woodward, indorsed by W. H. Bryan and C. W. Melcher.

Robert Moore, Chairman of the Committee on Relations with the Mercantile Library Association, reported having addressed a letter representing the views of the Committee to the Board of Directors. The letter had not yet been acted upon, but a reply was expected in time to report at the next meeting. The Committee was continued.

The Secretary reported having prepared an engrossed copy of the memoir on C. Shaler Smith as directed at the last meeting.

The special order of the day, a paper by H. S. Pritchett on "Mexican Longitude Determinations," was then taken up. The Club then adjourned to a room on the second floor specially prepared for the occasion. By the aid of the magic lantern the paper was fully illustrated. A complete description of the apparatus used, the method of making the observations and of computing the results were explained and the results were compared with those previously obtained with other methods. The professor showed a number of views of Mexican scenery and points of interest, with some remarks on peculiar features of the country and the characteristics of its people. The address was of decided interest. After answering some questions an invitation was extended to visit the time department of the Washington University, and the meeting adjourned.

WM. H. BRYAN, Secretary.

FEBRUARY 2, 1887:—Club met at 8:15 P. M. at Washington University, Vice-President Holman in the chair; twenty-three Members and seven visitors present. The minutes of the meeting of January 19 were read and approved. The Executive Committee reported the proceedings of its meeting of February 2, recommending Arthur J. Frith, Charles H. Ledlie and Edward K. Woodward for election to membership. On being balloted for they were elected members. The following applications for membership were announced and referred to the Executive Committee: Horace B. Gale, indorsed by William B. Potter and J. B. Johnson; Otto Schmitz, indorsed by William Bouton and C. H. Sharman; Arthur Thacher, indorsed by William B. Potter and H. A. Wheeler. The resignation of R. S. Hays, on account of removal from the city, was read.

Mr. J. A. Seddon then read a paper on "Efficiency of Cable Roads; its Variation with Length of Cable and other Elements of the Construction." Mr. Seddon called attention to the lack of reliable data on the subject, and the difficulty of ascertaining results reached by roads now in operation. The paper gave a thorough analytical and practical discussion of the subject, and was of decided value. Mr. Seddon gave some results of recent tests on the St. Louis cable road, but stated that the trials were not yet complete. The paper was discussed by Messrs. Johnson, Nipher, Adams, Bruner and Bryan. The hour being late, Dr. Adams'

paper on " Dynamo-Electric Machinery " was made the special order for the next meeting, February 16. Professor Nipher exhibited a piece of apparatus he had devised, for determining losses in the magnetic fields of dynamos.

[*Adjourned.*] WM. H. BRYAN, Secretary.

FEBRUARY 16, 1887 :—Club met at 8:15 P.M. at Washington University, President Potter in the chair; eighteen Members and three visitors present. The minutes of the last meeting were read and approved. The Executive Committee reported the doings of its meeting of same date, recommending H. B. Gale, Otto Schmitz and Arthur Thacher for election to membership. They were balloted for and elected.

The following applications for membership were announced and referred to the Executive Committee : Alex. E. Abend, indorsed by W. H. Bryan and F. E. Nipher; Chas. F. Muller, indorsed by M. L. Holman and Henry Flad; Max G. Schinke, indorsed by M. L. Holman and Henry Flad; Lewis Stockett, indorsed by W. B. Potter and H. A. Wheeler.

The Secretary read a letter from Mary G. Smith acknowledging receipt of the Club's testimonial to the late C. Shaler Smith.

The Secretary also read a communication from Jno. W. Weston, Commissioner-General for the United States for the Paris Railway Exposition and Jubilee, on the desirability of the Club being represented in some way. The matter was referred to the Executive Committee.

Dr. Wellington Adams then read a paper on "The Design and Construction of Dynamo-Electric Machinery," which was illustrated by diagrams and electrical apparatus. The subject was handled in a thorough manner, and a number of formulæ were given showing how the efficiency of any dynamo could be calculated. It was shown that these formulæ held the same relation to the dynamo machine that the indicator card does to the steam engine. The paper was discussed by Messrs. Gale, Nipher and Seddon.

The President announced the subject for the paper for the next meeting to be the "Present Aspects of the Problem of the Inter-Oceanic Ship Transfer," by Robert Moore.

[*Adjourned.*] WM. H. BRYAN, Secretary.

WESTERN SOCIETY OF ENGINEERS.

JANUARY 4, 1887 :—The 232d meeting was held at 7:30 P. M., Professor Cooley in the chair.

The minutes of the preceding meeting were read and approved.

Application for membership was received from Mr. Fred. Giddings, City and County Engineer, Atchison, Kas.

The following gentlemen were elected Members: Mr. Peter Heer, Manufacturer of Surveying Instruments, etc., 194 E. Madison street, Chicago.

Thomas T. Johnston, Assistant Engineer Chicago Drainage and Water Supply Commission, City Hall, Chicago.

Mr. Richard Price Morgan, Jr., Civil Engineer, Dwight, Ill.

Mr. Jason H. Shepard, Contractor, 2,449 Indiana avenue, Chicago.

The Secretary presented a photograph likeness received from Mr. Seth Dean, of Glenwood, Iowa.

In the absence of President Wright, the Secretary read the annual address of the President.

Mr. Benezette Williams, Manager for the Society in the Association of Engineering Societies, stated that the Society was now entitled to two representatives the Board of Managers, and tendered his resignation as Manager.

It was voted that the President appoint two Managers for the Society.

Mr. Williams presented a bill for the second installment of assessment of August 23, 1886, for expenses of the *Journal*, dated December 28, 1886, and amounting to $173, which was ordered to be paid.

Mr. Williams, as Chairman of the preceding meeting, announced the Committee on Letter from Professor Baker as I. O. Baker, L. P. Morehouse and Z. A. Enos

Officers for the year 1887 were elected as follows :

President, S. G. Artingstall.
First Vice-President, L. E. Cooley.
Second Vice-President, I. O. Baker.
Secretary, L. P. Morehouse.
Treasurer, A. V. Powell.
Librarian, G. A. M. Liljencrantz.
Trustee (for 3 years), H. A. Rust.

It was voted that a Committee, to consist of the President elect and two others appointed by the President, be appointed to report on the question of leasing rooms at the expiration of the present lease.

A paper by Mr. Barnabas Schreiner was read and discussed, " Views on Grades and Grade Systems for Cities."

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

FEBRUARY 1, 1887 :—The 233d meeting was held at 7:30 P. M.

Prof. L. E. Cooley was appointed Secretary *pro tem.*

The minutes of the preceding meeting were read and approved.

Applications for membership were received from :

Charles C. Breed, Resident Engineer, Maysville & Big Sandy R. R., Louisville, Jefferson County, Ky.

Simeon C. Colton, Engineer for Fitz Simons & Connell, 217 East Ohio street, Chicago.

Daniel W. Mead, City Engineer, Rockford, Ill.

Hubert A. Stevens, Assistant Engineer North Chicago Cable R. R., 145 Loomis street, Chicago.

William J. Yoder, Resident Engineer, Chicago, Madison & Northern R. R., Wayne, Du Page Co., Ill.

Mr. Albert F. Robinson was transferred from grade of Junior to that of Member.

Mr. Fred Giddings, City and County Engineer, Atchison, Kan., was elected a Member.

The annual report of the Secretary was read by the Secretary *pro tem.*

ANNUAL REPORT OF SECRETARY FOR YEAR 1886.

During the past year meetings have been held on the first Tuesday of each month at half-past seven in the evening, the attendance being considerably larger than heretofore, when two meetings were held each month, at four o'clock. Sixteen written papers have been presented and discussed. Seventy new members have been added to the Society. Two of the original members have died : Edward B. Talcott and Ellis S. Chesbrough.

For the coming year it would seem that special effort should be made to increase the membership. It must be borne in mind that the present annual dues of five (or six) dollars per member will not afford sufficient revenue for a proper expenditure until the Society has at least three hundred members. The membership list recently published shows less than two hundred names.

The address of President Wright, presented at the last meeting, refers to the general condition of the Society in such a manner as to make it unnecessary here to speak further on that matter.

The financial statement is as follows :

Total receipts for year 1886		$934.50
Total expenses		908.13
Balance for year 1886		$26.37
On hand Jan. 1, 1886		43.68
Cash in hands of Treasurer, Jan. 1, 1887		$70.05

Summary.

Receipts from dues		$934.50
Expenses.—Rent	$180.00	
Library	113.05	
Printing	100.08	
Postage, stationery, etc	68.75	
Portrait of President Wright	40.00	
Committee on National Public Works	30.00	
Journal of the Association of Engineering Societies	376.25	
		908 13
The receipts for 1885 were		869.80
The expenses were		838.96
The expenses for 1884 were		1,568 35

L. P. MOREHOUSE, *Secretary.*

The Committee on Letter of Prof. Baker made the following report, which was accepted and adopted :

Your Committee believe that the appointment of an engineer to have charge of the public highways of the counties and towns in this State would be in the public interest, but consider that it would be unwise at this time for this Society to ask for legislation to this effect.

The President announced appointments as follows :

Managers in Association of Engineering Societies—Benezette Williams, Lyman E. Cooley.

Committee on Rooms—Isham Randolph, C. E. Billin, C. L. Strobel.

A communication from Mr. S. A. Bullard was read, enclosing copy of a bill introduced in the Illinois State Senate, for "An act to provide for the examination and appointment of licensed surveyors."

The communication and bill were referred to a committee consisting of Messrs. Bullard, Enos and Baker.

The Secretary read a synopsis of a paper by Prof. Baker, "Formulas for Bearing Power of Piles." The writer asks for discussion after the full paper shall have been printed.

[*Adjourned.*]

CIVIL ENGINEERS' CLUB OF CLEVELAND.

NOVEMBER 9, 1886 :—Regular meeting held, President Latimer in the chair. The Recording Secretary being absent, the reading of the minutes of the last meeting was dispensed with. Mr. C. O. Palmer was elected Secretary *pro tem.*

Mr. H. F. Dunham read a paper on the Water-Works of Menominee, Mich. A general discussion of the paper followed.

Mr. J. F. Halloway, Chairman of the Committee appointed at the last meeting to prepare resolutions relative to the death of Col. Charles Whittlesey, presented the following :

Resolved, That in the death of Col. Charles Whittlesey, the Civil Engineers Club has lost an honorary and honored Member, whose contributions to the world of science have been both numerous and valuable.

That, while impaired health prevented him from meeting with us and forming acquaintances which would have been mutually agreeable, his written communications to the Club give evidence of his interest in its advancement and success.

Resolved, That we tender to his family and friends our sympathy in this their loss, and that if procurable his portrait be hung on our walls.

Mr. Halloway followed with a short biographical sketch of Colonel Whittlesey, in which he spoke of his having graduated from West Point; of his military services, his geological works, his engineering enterprises, and of his work in establishing the Western Reserve Historical Society of this city. Messrs. Latimer and Searles also spoke of the high character and standing of Colonel Whittlesey.

The resolutions were unanimously adopted.

[*Adjourned.*] C. O. PALMER, Secretary *pro tem.*

NOVEMBER 23, 1886:—Special meeting held, President Latimer in the chair. The resignation of Mr. Theodore Rosenberg as Chairman of the Committee on Architecture was received. President Latimer stated that Mr. Rosenberg had been called to a new field of labor at Colorado Springs, Col., and paid a just tribute to his industry and helpfulness in connection with the Club.

The President requested the Committee to select a new chairman as soon as possible.

Mr. J. L. Gobielle, Chairman of the Committee on Mechanical Engineering, read his report, showing the progress being made in that branch of engineering. The report brought out a very general discussion. Mr. Gobielle exhibited specimens of mitis, pure aluminum, and several of its alloys.

Mr. Rawson called the attention of the Club to a new book just published, "The Mechanics of the Girder," the last work of our respected and deceased member, Mr. J. D. Crehore.

[*Adjourned.*] C. M. BARBER, Rec. Secretary.

DECEMBER 14, 1886:—Regular meeting held, President Latimer in the chair. The minutes of the four previous meetings were read and approved.

Mr. Searles suggested that blank applications for membership be sent to each member, requesting them to present the blanks to their friends, hoping thereby to increase the membership of the Club.

The President appointed Mr. John Eisenman Chairman of the Committee on Architecture, vice Theo. Rosenberg, resigned.

Mr. Latimer stated that he had received a circular from the American Society of Civil Engineers in regard to a proposed union of all the engineering societies of the country, and asked if any previous communication had been received by the Society, and was informed that no such circular had been received.

Mr. L. Herman read a paper on the Erection of Spiral Stairways, in connection with stand-pipes, and also on the taking down of an electric mast. A discussion of the paper followed.

[*Adjourned.*] C. M. BARBER, Recording Secretary.

DECEMBER 28, 1886:—Special meeting held, President Latimer in the chair. The reading of the minutes of the last meeting was dispensed with.

The report of the Committee on Architecture being the order of the evening, Mr. J. N. Richardson read the report. A general discussion of the paper followed.

[*Adjourned.*] C. M. BARBER, Rec. Secretary.

JANUARY 11, 1887:—Regular meeting held, President Latimer in the chair. In the absence of the Secretary, Mr. A. Mordecai was elected Secretary *pro tem.* Messrs. W. B. Pearson and Charles E. King were elected Active Members of the Club. The Treasurer was, on motion, authorized to pay the Janitor of Case Library $10 for services rendered in the Club rooms.

The following resolution by Mr. Hosea Paul was adopted:

Resolved, That a special committee of five members be appointed to consider the question of the adoption of standard time, and report to the Club what action, in its opinion, is advisable. The following committee was selected: Chas. Latimer, Chairman; Hosea Paul, Professor Morley, J. F. Halloway and W. H. Searles.

Mr. N. B. Wood presented a paper on natural gas, which was very generally discussed by the members.

[*Adjourned.*] A. MORDECAI, Secretary *pro tem.*

ENGINEERS' CLUB OF MINNESOTA.

MINNEAPOLIS, MINN., JANUARY 14, 1887:—Regular and annual meeting of the Engineers' Club at City Hall. Mr. Jno. H. Barr, G. W. Sublette, Wm. W. Redfield, M. J. Riggs, Mr. J. Hazen, Geo. W. Cooley, F. W. Cappelen and W. S. Pardee were present. Mr. Barr, President pro tem. Minutes of previous meeting were read and approved. Mr. P. B. Winston was elected member of Club, and the name of F. C. Deterly was proposed for membership, certified to by Geo. W. Sublette and W. W. Redfield.

Annual report of Secretary on financial condition of Club was read, and auditor W. W. Redfield was appointed to audit the report.

On motion Club proceeded to the election of officers:

Mr. G. W. Sublette, President.

Mr. Jno. H. Barr, Vice-President.

Mr. W. S. Pardee, Secretary and Treasurer.

Mr. Geo. W. Cooley, Member Board of Managers Associated Engineering Societies.

Discussion: Heating and Lighting of Railroad Cars.

[*Adjourned.*] WALTER S. PARDEE, Secretary.

FEBRUARY 11, 1887:– Regular meeting at City Hall, President George W. Sublette in the chair. Members present, Wm. W. Redfield, J. H. Barr, M. J. Riggs, Geo. W. Sturtevant, Wm. R. Hoag and Walter S. Pardee.

Minutes of previous meeting were read and approved. Mr. F. C. Deterly was duly elected a member of the Club. The names of Franklin Cook, certified to by G. W. Sublette and Walter S. Pardee; Mr. P. M. Dahl, certified to by Geo. W. Sturtevant and G. W. Sublette; and Mr. C. O. Huntress, certified to by G. W. Sublette and G. W. Sturtevant, were proposed for membership. Auditor Redfield certified to the correctness of the Secretary and Treasurer's report for 1886. Report was adopted and ordered filed.

Mr. President announced the standing committees for the year:

On Library and Literature, Government—Mr. President, Vice-President, Secretary, Treasurer and Librarian.

Bridges and Materials—F. W. Cappelen, M. J. Riggs and Wm. R. Hoag.

Railroads and Transportation—J. W. Kendrick, E. T. Abbott and M. D. Rhame

Sewers and Drainage—F. W. Carr, W. W. Redfield.

Engineering Jurisprudence—Jno. Lamb.

Building Materials and Sanitation—Fred. Kees, J. M. Hazen, G. Sidney Houston.

Rivers and Canals—D. P. Waters, G. W. Sturtevant, F. H. Todd.

Streets and Paving—G. W. Cooley, C. E. Sprague.

Surveying and Topography—F. L. Straw, A. C. Libby, Frank Plummer.

Weights and Measures—W. S. Pardee, Robt. Augst, Edwd. Barrington.

Machinery—R. H. Sanford, J. H. Barr, Wm. De Le Barre.

Water Supply—James Waters, D. P. Waters.

Municipal Engineering—A. Rinker, Wm. De Le Barre, E. T. Abbott, Wm. Vanduzee.

Contracts and Management of Work—P. B. Winston.

On motions the Secretary was instructed to correspond with the Chairman of Committee on Harbor and Shipping, Wm. Foster Higgins, asking for copies of pamphlets, and maps or plans of New York harbor that may be at his disposal. Subject of coast defense was referred to Committee on Rivers and Canals to re-

port at next meeting. Discussion of the evening: Coast Defense at New York and Heating of Railroad cars. Subject of car heating was referred to Committee on Railroads and Transportation, with instructions to prepare report at next meeting.

On motion the rules were suspended, and the resolution submitted that the By-Laws be amended as follows :

Resolved, That Art. 1st of By-Laws be amended to read: The regular meetings of this Club shall be held at 7.30 P. M. on the second and fourth Fridays of each month from November 1st to May 1st, and on the evening of the second Friday of each month from May 1st to November 1st.

[*Adjourned.*] W. S. PARDEE, Secretary.

FEBRUARY 25, 1887 :—Special meeting of Civil Engineers' Club of Minnesota, 8 P. M., Mr. President in the chair. Members present, M. J. Riggs, Wm. W. Redfield, Geo. W. Sturtevant, F. H. Todd, F. W. Cappelen, G. S. Houston, W. S. Pardee.

Minutes of last meeting read and approved.

Special meeting—no regular business.

Discussion for the evening : Factors of Safety. Discussion opened by Mr. Houston. Active part taken by F. W. Cappelen, G. W. Sublette, M. J. Riggs and others.

On motion of Mr. Houston the Committee on Buildings was instructed to confer with the Committee of the Architectural Association having in charge the bill providing for the licensing of architects, with reference to the formulating of an amendment to said bill to provide for a factor of safety to be used in the construction of buildings.

[*Adjourned.*] W. S. PARDEE, Secretary.

MARCH 11, 1887 :—Regular meeting at City Hall, 7:30 P. M., President G. W. Sublette in the chair. Present—J. H. Barr, Wm. R. Hoag, Wm. W. Redfield, M. J. Riggs, and G. W. Sturtevant. The Secretary being absent, G. W. Sturtevant was appointed pro tem. Records of the previous meeting were read and approved. The Secretary read a letter from H. M. Waitt relative to continuance of membership ; also a letter from Hon. C. K. Davis relative to copies of U. S. Reports for the Club library. On motion it was unanimously voted to adopt the resolutions passed at the last regular meeting to change Art. I of the By-Laws as per resolution. Mr. Barr presented a communication from Prof. Wm. A. Pike inviting the Club to hold its April 9th meeting at the College of Mechanic Arts, State University, and have an opportunity to inspect the apparatus of the various mechanical departments. Invitation accepted. On motion, C. O. Huntress, Franklin Cook and P. M. Dahl were elected to membership. The discussion of the evening was on New York Harbor improvement, which was chosen as the subject for the next meeting. The President gave notice that he would read a paper on Railroad Bridge Openings at the next meeting.

[*Adjourned.*] WALTER S. PARDEE, Secretary.

MARCH 25, 1887 :—Regular meeting of the Civil Engineers' Club of Minnesota was held Friday, the 25th inst., at 7:30 P. M., at the City Hall. Mr. George W. Sublette in the chair. Other Members present were : G. S. Houston, Wm. W. Redfield, F. C. Deterly, Geo. W. Sturtevant, F. W. Coppelen, M. J. Riggs, and Mr. Secretary.

After the reading and approval of the previous minutes, the standing committees reported on the subjects assigned to them.

In the following evening discussion Geo. W. Sturtevant, of the Committee on Rivers and Canals, continued the subject of New York Harbor and Coast Defense. Committee on Weights and Measure outlined the theory of Pro-

fessor Kedzie on the cause of the "Attraction of Gravitation." The paper of the evening was read by President Geo. W. Sublette on Railroad Bridge Openings. Paper illustrated by black-board and paper diagrams. On motion of Mr. Houston the subject of Wire Ropes were adopted for the next meeting, which is to be held at the University of Minnesota second Friday in April.

[*Adjourned.*] WALTER S. PARDEE, Secretary.

Editors reprinting articles from this journal are requested to credit both the JOURNAL *and the Society before which such articles were read.*

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

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This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

ARCHITECTURAL ENGINEERING.

BY J. N. RICHARDSON, MEMBER OF CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read December 28, 1886.]

There was a time in the long ago when architects were engineers and engineers were architects. I allude to Civil Engineers, those whose province it is to deal with construction.

They were then known only as architects, and we have still many remaining examples of their engineering skill, from the simple construction of the early temples to the complex vaulting of the middle ages. These all attest that the men who designed them paid a strict adherence to mechanical laws—they worked as an engineer of to-day works, considered the nature of the materials at their command, and applied them to the case in hand in the best possible manner. They considered well their loads, lines of forces and strains produced, and arranged and shaped their materials accordingly. They had to do so, or their structure would not have stood, nor would many of ours stand to-day under the same circumstances—that is if our constructions were as honest as theirs, and showed on their face just what they were. What falls there would be of all the arched aisles and vaulted ceilings we see in our churches were of stone (as they pretend to be) instead of lath and plaster, if even many of the arches which *are* of brick or stone were not sustained by some hidden power, as a strong rod or iron beam.

One of the characteristics of this age is that which might be designated as the divorce tendency, the tendency of separating a being which is of one flesh into two or more. Thus the carpenter of the past generation, who could frame his structures from hewing the timber to making the doors and windows and finishing the inside, has been divided into the framer, planer, sticker, sash, door and blind maker, stair builder and inside finisher ; the shoemaker into the leg maker, upper maker, bottomer, etc., all the trades share the same fate. The ancient architect is no exception ; he also has been resolved into his original elements of architect, engineer, sculptor, decorator, etc., and thus we find him to-day the shattered remains of his former greatness.

If the influence of this Club will in any way conduce to getting him, together again it will not exerted in vain.

The progress of architecture during the past ten years indicates that

the coming architect will be more of an engineer than those of say twenty years ago, not only that he will possess more technical knowledge and be better versed in the laws of mechanics, but that the spirit of truthfulness will pervade his structures to a greater extent, so that the real construction will show itself as it does in purely engineering works. The engineer makes no shams, and architects are giving up the practice. It is not considered necessary now to plan a make-believe chimney on the left side of a roof because a real one is on the right, nor that window sills should all be on a level, even if a stairway does run across them, nor many other false notions of symmetry, which we are gradually getting rid of.

This principle of engineering—honest expression in all the members of a structure—if practiced by architects, coupled with a true artistic treatment, will do much to bring our buildings up to the standard of those monuments of the earlier ages.

If an infusion of engineering sentiments into the architect will benefit his structures, might not a like infusion of art feeling into the engineer improve his? What is more artless than a railroad bridge? Whether it is possible to give it a more artistic appearance without increasing the cost is a question which will bear considerable discussion; also whether companies who build them would pay the extra cost if there should be any. They don't object to do it in their depots; it may be that the architect puts it on anyhow cost, or not, and the companies cannot help themselves.

It has been remarked by a writer on architecture that every structure which is erected detracts to a certain extent from the public enjoyment; that is, it shuts off or obstructs the view of the landscape. They should, therefore, be compensated for their loss by making the structure interesting. This is the true estimate of architecture. *True* art cannot be applied to a structure; it must be woven into it, be part and parcel of its make up.

Professor Huxley, while lecturing some years ago before the Johns Hopkins Hospital, gave them advice regarding their then contemplated new building. He told them, whatever they did, not to go to an architect, but to get a good, honest mason, tell him what they wanted, and let him build it; then if they had money left when they got through with the mason, they might hire an architect to put a face on it.

This illustrates the prevailing idea of architectural art—putting a face on; and this opinion, shared to some extent by even architects, has been a hindrance to the advancement of real architecture.

The engineer who would give art expression to his structures must be a student of art, so as to weave it in with the bone and sinew of his work; and the architect who would bring his structures up to the standard of monumental art must be actuated by those engineering principles —honest and truthful construction.

DISCUSSION OF MR. RICHARDSON'S PAPER.

Mr. W. H. Searles: Pilate asked, "What is truth?" And we may ask, What is art, and what is beauty? There is some difficulty in giving a definition. Our tastes change with custom. It has been suggested that

railroad bridges are not beautiful. The older forms of bridges seem to us somewhat graceful, for instance, an old wooden bridge with an arched upper chord. If we take a more modern bridge with a heterogeneous upper line and the contour broken, it may appear at first unsightly; it is evidently constructed to meet the requirements of the situation and not with reference to the taste of the beholder. Later on, however, when the adaptability of this bridge to its purpose is understood, we learn to consider it beautiful. The clumsy elephant may appear to have no beauty, but when we see him exert his strength, and observe his wonderful construction, we find beauty in it. There is a beauty of the racehorse, and another beauty of the elephant. There is a beauty of the cathedral, and a beauty of the railroad bridge, yet they may not be compared. As certain styles prevail, and we see that they are requisite for their purpose, they become beautiful in our eyes.

Mr. C. O. Arey: I do not quite agree with Mr. Searles. One of the essentials of beauty is proportion. If we see structures that are not correctly proportioned, custom cannot make them beautiful to us. One reason why many engineering forms fail to please us is on account of this lack of proportion. The French engineers have to study architecture in connection with engineering, and their structures have a much better appearance than the American.

Mr. S. J. Baker: Our Superior street viaduct is an illustration of the lack of proportion. Looking at it from a distance it appears to me as if there was not depth enough between the roadway and the crown of the arches, and as if the hand rail was too light. In looking at pictures of large viaducts in Europe I have observed how much attention was paid to the proper proportions of the railing and ornamental lamp-posts. Our structure appears deficient in this respect.

Mr. Barber: The construction of engineering works is controlled more by the idea of their usefulness than of their beauty. Structures made on purely theoretical lines would be more beautiful. In the suspension bridge, the curve of the upper cable is very graceful. If we could build trusses on theoretical lines they would present a finer appearance. We build a square end truss because it is more economical. Take, for instance, a simple truss loaded uniformly, the bottom chord would, theoretically, be a regular curve. There is a great beauty in a stone arch, yet when we build arches in iron we have to deviate more or less from the theoretical lines. We often see ornamental forms like brackets, which do not have the appearance of supporting anything. This detracts from their beauty. Ornamentation is more beautiful when it appears to be really of service.

Mr. Richardson: I have always held it as a principle that truth in architecture was essential to beauty. Mr. Barber is right with regard to brackets. It offends good taste to see a bay without any visible means of support. Even if an architectural feature has the appearance of doing some work, it looks better to us. I find no beauty in shams. I believe St. Patrick's cathedral in New York has a vaulted ceiling which is made of lath and plaster. I have seen arches in Cleveland which, if they were made of stone, as they appear to be, would certainly fall. I think there should be as much truth spoken from the walls of a church as there is

from the pulpit. Churches to-day have pillars for appearance only. Trinity Church in this city is one of the most honest in this respect. For that reason I have always thought it one of the most beautiful. The structures of the Middle Ages were fine pieces of engineering. Those old architects must have known a good deal of engineering principles. To-day pinnacles are made of galvanized iron put on for appearance only, then they were pieces of engineering.

Mr. W. H. Searles: Among the competitive designs for the new Harlem River bridge was one very handsome, which was not chosen by the commission. In my judgment that which was accepted was quite inferior.

Mr. Richardson : The East River Bridge is a beautiful structure. The only parts subject to adverse criticism are the piers. The engineers tried to put some architecture into them. If they had followed the same principles in building the piers as they did in other parts of the structure, they would have been in much better taste.

Mr. Latimer : I think that any form must be symmetrical to be beautiful. Take for instance something that we use very often—a Tyler or Wharton's switch. Some persons admire it, but in my opinion it is cumbersome and unsymmetrical and loaded with heavy casting, a split switch has a much better appearance, Mr. Searles says that our views of beauty change with custom, and that forms at first considered unsightly become beautiful to us. You will remember that Horace loved his friend Balbenus so much that he fell in love with his wen.

Mr. Arey : Balance is necessary to beauty. Take for instance Mr. Richardson's remark about chimneys. If you have a chimney on one side of the house, you must put something on the other side to balance it, though not necessarily another chimney.

Mr. Baker : A thing may be symmetrical without being beautiful. The elephant may be symmetrical. Beauty is to a large extent in the eye of the beholder. Different nations, for instance, differ widely as to what constitutes female beauty.

Mr. Searles : I think our ideas of beauty may be regulated somewhat by a study of nature. Take for illustration the rose ; it is beautiful, yet not one rose in a thousand is perfectly symmetrical ; one side will be developed more than the other. Some flowers, as the calla, are all one-sided, yet their beauty is unquestioned. We are at liberty to follow the same principles in our structures ; there may be fineness and beauty without regularity of parts. I do not wish to be understood to assert that any form may come to be considered beautiful after long acquaintance with it. There are principles of beauty in architecture without regard to the whim of the individual or the fashion of the hour. I would suggest that we should be favored with an outline sketch of the East River Bridge by Mr. Richardson. I have often studied those piers and have felt offended with them. I do not like the gothic arch, and the general outlines cannot compare with the beauty of the rest of the structure. They are too plain, and yet their plainness does not give them dignity.

Mr. Richardson : If the piers were massive they would have more dignity. The porticoes of the Doric temples had very little ornamenta-

tion, yet no one claims that they had not dignity. I read some time ago a fine criticism on that East River bridge and on the piers. I wished to bring it here this evening, but failed to find it.

Mr. Barber : I understand that Mr. Roebling considered the piers of the Cincinnati bridge to have architectural beauty. He was disappointed when the city refused to have the bridge at the end of Vine street ; he thought that it would improve the appearance of the street. He speaks of those piers as if he had paid a great deal of attention to the architectural effect. It shows that engineers sometimes have taste in design.

Mr. Barber : If the elder Roebling had lived to finish the East River Bridge, perhaps the piers would have been more beautiful.

Mr. Arey : Mr. Searles' illustration, the calla, has neither balance nor symmetry. The lady-slipper is still more unsymmetrical. As far as we can discern, this is true of nearly all of the works of nature.

Mr. Latimer : The architecture of the day, especially in this country, does not appear to symbolize or commemorate anything. I have observed the great attention paid by the old architects to geometrical and astronomical forms. Take Notre Dame, in Paris ; it is built in honor of the Virgin Mary ; all the signs of the zodiac are shown in it except the Constellation of Virgo. All great structures ought to commemorate some great thought. Of course you will expect me to speak of the Pyramid. The structure, in the first place, shows finer workmanship than that of the present day. How many buildings to-day have their cement so fine that it does not exceed one-hundredth of an inch in the joints? How many have their joints so fine that they cannot be discovered? This can be found in Central America, in architecture which must have existed before the flood, similar to that which is found in Egypt to-day. Almost all of those early structures specially symbolized something. Those early builders seem to have left Egypt, as that wonderful architecture was not continued there, but it passed into Greece and Rome. Those early builders possessed accurate knowledge for the selection of material for strength and durability. They always seasoned their stone.

Mr. Richardson : The idea of commemorating some special thought is adopted to some extent in churches; but in other buildings, such as business houses, the endeavor is only to adapt them in the most appropriate way to the business to be carried on in them. In a dwelling a good deal depends on the man who is to occupy it. If his dining room is very large and his library small we may imagine that he cares more for the pleasures of the table than for the improvement of his mind. If his billiard room is only fitted to contain tables we may know that the man cares merely for the game ; but if it is furnished with books and pictures, easy chairs, and so forth, we believe that he likes to entertain his friends. Churches sometimes commemorate some great event in their carving. We cannot complain that the new Masonic Temple has no commemorative designs.

Mr. Whitelaw : Did Mr. Richardson see the articles on architecture by Miss Van Rensselaer in the *Century?*

Mr. Richardson : Yes, I think she is the best writer of the day on that subject.

Mr. Whitelaw: The leading idea seemed to be that the structure should speak for itself. Various illustrations were given, such as a malt-house, a manufactory, a hospital. Any one looking at the picture would understand at once for what purpose the building was designed.

Mr. Richardson: It is true art, and truthfulness in art, to have the building designed so as to represent the function that it performs.

Mr. Searles: One criticism of the obelisk is that there are no shadows. Both the obelisk and the pyramid are perfectly plain surface figures. They appeal to something in us. The East River Bridge, while it throws a shadow, has a broken outline. There is no gradual taper. The walls seem to be vertical. They are inclined for a short distance and then become vertical again. More elaborate styles of architecture have cornices and projections casting shadows. The East River Bridge has none to speak of: nothing suited to so bald and heavy a structure, especially when it is in combination with so graceful a structure as the Suspension Bridge.

Mr. Latimer: The obelisk is in direct contrast to the pyramid. The pyramid embodies strength and durability.

Mr. Arey: The American architect is beginning to have some credit in private work. The individual owner seems to understand that he knows something; but in public edifices he is hampered by the building committee.

Mr. Barber: There are two great structures being built at the present time. One is to my mind most hideous; the other, very graceful. I refer to the great cantilever bridge over the Frith of Forth, and the French Tower.

Mr. Richardson: I think the drawings of the French Tower look graceful, and so do those of the Forth River bridge. It has curve lines; the Niagara Bridge has sharp lines.

Mr. Barber: Is not that tower intended to represent the architecture of the present day?

Mr. Richardson: I believe it is; that is, the architecture of the present day with the materials we have. If the architects of the middle ages had possessed materials such as we have, they would have made as fine forms in them as they did in the materials they had. If a man has true art feeling it will show itself. As it was said of a poet, "He lisped in numbers, for the numbers came." Take a simple thing like the nut of a bolt, make it hexagonal, round it a little and it will look more refined.

Mr. Hermann: Our cast-iron machines were formerly provided with a number of projecting ribs. Engineers lately have begun to smooth off the exterior and to put the ribs inside. No protruding part is allowed to be seen. The machines now reoresent strength. It is difficult for designers to adopt new principles such as these designs embody, and much credit is due to them.

Mr. Swasey: The idea is to have the surface as plain as possible, and to leave off every unnecessary projectien. We get better castings. The molder can slick them off better, and keep them in better shape. Most machine tools now are built on the column plan, with the ribs inside. It is very different from the time when we used to find architectural columns on pumping engines.

Mr. Latimer : Are you not engaged in making the Lick telescope?

Mr. Swasey : Yes ; it has a hollow column, about 35 feet high, 4 by 8 feet at the top. It is made in sections. All the castings are as smooth as possible, with the ribs inside. In the modern construction of telescopes, it has been found best to build the columns of iron, and everything practicable is placed within them. Instruments have been built principally in foreign countries, and a great many improvements in their construction have been made. We now strive to build a telescope as a machine, not as an instrument.

Mr. Wood : It appears to me that it requires a much higher quality of skill to give smoothness and finish with this simplicity of construction than with the former method of ornamentation.

Mr. Richardson : It is a good deal more difficult to make a building look well without any decoration. It was said of one architect, Mr. Street, that he could take the simplest conditions and produce a good effect, but it required great skill to do it.

Mr. Swasey : With regard to molding, of course, cast iron enters largely into machine tools, and it is quite a problem to make them plain and still preserve a good appearance. It requires a good deal of experience to get any one out of the old rut in designing machinery, but mechanical engineers are being educated in the more modern methods of construction.

Mr. Richardson : Mr. Eastlake stated that when he first bought furniture for his house, he saw some chairs with a number of fancy accessories on them. He inquired how much they would cost without these, and the manufacturer named a much larger price. He explained that it would be more difficult to make them presentable without this decoration.

ANNUAL ADDRESS

TO THE WESTERN SOCIETY OF ENGINEERS.

By President Augustine W. Wright.

[January 4, 1887.]

Gentlemen : In compliance with your By-Laws, I would respectfully submit the following report :

The accompanying reports of the Secretary and the Treasurer will indicate to you the present condition of the Western Society of Engineers, as regards the gratifying increase of membership, but I would urge upon you, individually and collectively, the importance of continuing your efforts to add to your membership.

I cannot refrain from expressing to you my mortification at the lack of interest evinced by the majority of our members, as evidenced by the dearth of papers and comparatively small attendance at the meetings, although I must admit that in the latter respect there has been a marked improvement over the preceding year. Soon after you honored me with an election to your presidency, I called upon nearly every resident member and solicited his hearty co-operation in furthering the interests of the Society.

In appointing your standing committees, I endeavored to select those who I imagined would take an active interest in the subjects allotted

to them. The result in the majority of instances would indicate that the gentlemen selected did not enter actively upon the discharge of those duties. There has been a dearth of papers and discussion, as above mentioned, and this can only be rectified by an earnest effort upon the part of members, an effort that I most sincerely trust may result from this plain statement of facts.

The venerable Telford, in his inaugural address of the British Institute of Engineers, spoke as follows :

"It becomes incumbent on each individual member to feel that the very existence and prosperity of the Institution depend in no small degree on his personal conduct and exertions ; and my merely mentioning the circumstance will, I am convinced, be sufficient to command the best efforts of present and future members."

If your Society is to be continued, to be made useful and interesting to its members, so greatly desired a result can only be accomplished by the personal efforts of members. Let me, therefore, beg that each one will consider himself personally addressed, and urged in the most emphatic language to contribute to the success of our society by attendance at the meetings, as much as possible, and by furnishing papers, asking questions, answering questions, stating the result of his experience, failures and successes. This will infuse new life into your Society and make it a power for the accomplishment of much good.

The task of submitting to you a summary of the important Engineering works of the past year would be difficult of performance, for I question whether ever before within the history of the world has there been more universal activity in the various departments of engineering. I will confine myself, therefore, to a few of the more important achievements within our own territory.

Twelve months since, I looked confidently to a vast stride forward in the effort to produce electricity at a cost that would enable it to compete with steam. As you well know, the most perfect steam engines utilize comparatively only a small portion of the theoretical energy contained in the coal consumed. Able electricians have been earnestly striving for some method of converting this energy stored in the coal *directly* into electricity, without the intervention of the steam engine, but, so far, without success. The conversion of the energy in the coal into electricity through the intervention of the steam engine and dynamo, and then its reconversion into power entails such serious losses that competition with steam as a motive power is precluded except in a few instances.

The application of electricity to smelting has resulted in the construction of a mammoth dynamo for the Cowles Smelting Co. It was completed the past season by the Brush Co. at Cleveland, and is said to be the most powerful electric machine in the world, its capacity being 3,800 ampères and 100 volts E. M. F., over 510 electrical horse-power ! This machine is located at Lockport, N. Y., driven by water-power and used for the extraction of aluminum from corundum.

W. H. Hale, Ph. D., wrote, "But the furnace gives many other products. Sometimes there are found small fused rubies and sapphires. The sub-oxide of aluminum never found in nature and never before known to exist, or to be capable of formation, is always present in larger or

smaller quantities. I have also seen specimens of beautiful white, fibrous alumina. With other charges, sub-oxide of silicon and titanium are found, very curious products indeed. The intense heat even partially fuses the carbon, and the electrodes are converted into graphite. Important economical as well as scientific results have been already attained by the dynamo. The price of aluminum alloys has been reduced to a scale adopted by reckoning the value of the contained aluminum at $2.50 per pound, previous sales of that metal having been made at 75 cts. per ounce. The 10 per cent. alloy is said to be the strongest metal known."

The vast number of people dependent upon the daily transportation afforded them in the cities and towns of our country make everything affecting the speed and regularity of said transportation a matter of interest. Beyond question, the elevated railway affords the best result in this respect, and statistics, it is claimed, can be produced to prove that even property directly along the right of way is benefitted by such a construction. For surface transit in the streets, the cable system is meeting with wide-spread adoption. It is an American invention as now built, and may be said to have originated with the construction of the Clay Street Hill Railway, of San Francisco, Cal., in August, 1873. It has also been introduced in the cities of Chicago, St. Louis, Kansas City, Los Angeles, Oakland, Omaha, New York, Brooklyn, Philadelphia; and many other cities are now contemplating its adoption.

The different roads have cost from $30,000 to $105,000 per mile of single track, varying with the manner and difficulties of construction. Beyond question it affords, when properly constructed and operated, increased accommodation to the people seeking transportation as compared with animal power.

Regarding steam railroad interests the mileage has increased until it is estimated that we now have 137,000 miles in operation.

One of the most important events affecting this interest from an engineering point of view was the power brake test near Burlington upon the Chicago, Burlington & Quincy Railway in July last. I would respectfully refer you to the files of the *Railroad Gazette* for a very full account of "what is unquestionably the most thorough and careful attempt to settle a complicated mechanical problem which has ever been made in this country."

Great activity has existed among those members of our profession engaged in bridge building. Among the important bridges recently completed in this country is the Henderson Bridge across the Ohio River, formally opened for traffic August 5, 1885. It is 3,688 feet in length, of which the channel span is 525 feet, from centre to centre of piers. It has 16 spans proper and three supplemental and smaller spans. The channel span is 100 feet above low water.

The Baltimore & Ohio Railroad bridge over the Susquehanna River is 6,315 feet in length; one span 520 feet, and four spans 480 feet in length each. A gratifying event to the professional pride of American bridge engineers was the award in January last of a contract to the Union Bridge Co., of New York, to construct a double track steel bridge over

the Hawkesbury River by the Government of New South Wales. The bridge is to be 3,000 feet in length, consisting of seven spans. The foundations are to be sunk to the unprecedented depth of 170 feet below tide water. The bridge over the Schuylkill River, at Philadelphia, is a skew bridge, angle 53° 15′. Four pneumatic caissons were sunk for foundations, the deepest having gone 80 feet below water surface. Considering the difficulties, this work was completed in an unusually brief time.

During the past summer the great undertaking was successfully accomplished of changing the gauge of nearly 11,500 miles of railroads throughout the Southern States to a uniform gauge of 4 feet 9 inches, the standard of the Pennsylvania Co. This was done within forty-eight hours and, so far as I have been able to learn, without accident or delay, and may well be considered an achievement worthy of note.

The use of natural gas continues to increase, and affects many branches of engineering. The eighth edition of the Directory of the Iron and Steel Works of the United States, corrected to July, 1886, shows that 68 rolling mills and steel works are using this fuel, and 16 are making preperation to introduce it. Two years ago not more than six rolling mills and steel works used natural gas as fuel.

In concluding this brief summary, gentlemen, I would impress upon you the fact that you are members of "no mean" profession and point with pride to the achievements that have resulted from the efforts of members of your profession in the past. Their labors have been second to none in behalf of the material prosperity of mankind, and it is largely due to them that a laboring man of to-day enjoys comforts in his home denied to the crowned heads of a few generations past.

But Jeans wrote: "Next to the illimitable nature of the field there is for the exercise of genius, what is more likely to stimulate exertion in this direction than a knowledge of the rewards and honors gained by those who, although the foremost men of our day, still say they have only gathered a few pebbles from the vast ocean that lay before them?" These words are true, and I can only hope that as day by day we gather wisdom with experience, that wealth and fame may be the reward achieved by each member of the Western Society of Engineers.

THE GREAT WATER WAY TO CONNECT LAKE MICHIGAN WITH THE MISSISSIPPI RIVER, AND ITS INFLUENCE ON FLOODS IN THE ILLINOIS RIVER.

By Thos. T. Johnston, Member of Engineers' Club of St. Louis.

[Read January 5, 1887.]

It may now be said to be a settled fact that an artificial water way of unprecedented magnitude will soon connect Lake Michigan with the Mississippi River by way of the Illinois River. This water way will be large enough to easily permit the largest boat that visits St. Louis to pass into Lake Michigan, and may in the near future permit lake boats to take cargoes from St. Louis to Buffalo.

The necessity for and merits of this water way were made manifest in a report to the Citizens' Association of Chicago, in August, 1885, by Mr.

L. E. Cooley, C. E., who was at that time the engineer representative on the committee of the Association. With this report as a basis, the Association prevailed upon the city officials to investigate the question to which it pertained, namely, the future drainage and water supply of Chicago. Mr. Rudolph Hering, C. E., and Mr. Benezette Williams, C. E., as sanitary experts, were constituted a commission with this end in view, with Mr. Cooley as their principal assistant.

The question turned on the preservation of the waters of Lake Michigan and of the Illinois River from objectionable pollution by sewage. All possible schemes to this end have been examined, and, though the commissioners' report has not been made, they have publicly announced through the press and otherwise, that by far the cheapest and best answer to the question is furnished by a water way connecting Lake Michigan with the Mississippi River, thus indorsing the conclusions previously reached by Mr. Cooley.

If the level of Lake Michigan was only ten feet higher than it is at present its waters would flow over the natural divide that separates it from the Mississippi, and would flow through the upland tributaries of the Illinois River, and thence toward the Gulf of Mexico. Already this natural divide is cut by a canal, which is fed by the lake. At present the sewage of Chicago, mixed, according to the season, with from four to eight parts of lake water, finds its way through the canal at the rate of 50,000 cubic feet per minute. The result is a densely polluted stream for some miles from Chicago. The city is growing rapidly and the stream getting worse, and the State Board of Health is demanding more dilution with lake water.

In a paper prepared by invitation of the Commercial Club, of Chicago, and recently read before them, and well received by them, Mr. Cooley stated that the requirements of the case demanded an enlarged canal which should at first have a cross-section of 2,000 square feet and a depth of about 20 feet. This canal, to cross the divide, must be about 30 miles long. The quantity of water to pass through it should be in excess of 6,000 cubic feet per second, or 360,000 cubic feet per minute. In the course of thirty or forty years, if the city should grow at the rate anticipated, the canal should be enlarged so that about 15,000 cubic feet per second, or 900,000 cubic feet per minute, should flow through it.*

Without stopping to discuss further the many interesting topics this water way suggests, the purpose of this paper will be reached at once.

The hydraulic considerations entering in the design of this water way do not cease with having delivered the water thirty miles from Chicago. Having reached this distance the water will pass through a dam or lock into the natural channel of the Des Plaines River, and thence into the Illinois River. It has been said that "the people of Illinois will want to know how this large volume of water will get through these channels."

The question turns, of course, on the manner in which floods will be influenced. When the writer was in the service of the Mississippi River

* It is easy to see that the channel having the largest hydraulic radius consistent with velocities suitable for navigation will require the least excavation. Mr. Cooley speaks of 20 feet deep by 10 et wide, so arranged as to be ultimately widened to 250 feet.

Commission his duties pertained largely to the question of flood discharges. Certain facts were correlated and conclusions drawn, the ideas involved in which have been variously presented. Since that time some experiments on the flow of water in the Chicago water supply conduits have been examined, which forcibly illustrate the ideas then presented, and which have a bearing on the subject above described. It is desired to present the results of these experiments and to discuss them in the new light they throw on the question of flood discharge. In doing this pardon is asked for briefly reviewing two familiar facts in order to lead up more precisely to the particular ideas which it is intended to consider.

Two long steps have recently been made in the advance of our knowledge of the flow of water in defined channels:

First. This step may be stated as being the result of the discovery of the influence exerted on flow by the nature of the wetted surface. For example, suppose a straight channel, with uniform cross-section, to be constructed, and let it have a uniform inclination. In one instance let its surface be made of rough brick work, and in the other instance let the surface be of cement evenly put on. When equal depths of water are flowing the discharge in the latter will be very much greater than in the former instance.

Second. This step may be stated as being the result of the discovery that the increase of velocity as the hydraulic radius increases takes place at a more rapid rate than is expressed by the square root of the hydraulic radius. It has always been recognized that a straight and uniform channel having a constant inclination and constant form will have varying velocities if its size be varied. It was formerly supposed that this increase of velocity was proportional to the square root of the hydraulic mean depth, or the hydraulic radius. More recent experiments have proved, however, that this supposition was not well founded, their results showing that, other things being equal, the velocity in a channel increased more rapidly as the size or hydraulic radius increased.

This paper is intended to deal with ideas more particularly analagous to the first step of advance, namely, the influence exerted on flow of water by the nature of the boundaries of its channels. Some use of the second step will be made incidentally.

The experiments on the flow of water in channels upon which the various formulæ have been based have been made almost without exception in straight and uniform channels with uniform inclinations. There can be no doubt as to what is meant by a straight channel with uniform inclination, but the term "*uniform channel*" needs some explanation in order to avoid misunderstanding.

Consider a channel, every cross-section of which has the same shape and size. This channel will be uniform as to shape.

Impose the condition that the channel must have a *continuous surface.* The channel will then be uniform as to surface.

Impose further the condition that the surface of the channel must be continuously of the same kind of material and the same degree of roughness. It will then be uniform as to construction.

Having met all these conditions, the channel may be said to be uniform.

The channels met with in practice are rarely straight and uniform channels with uniform inclinations. Uniform inclinations sometimes occur, and likewise straight channels; but uniform channels are very rare.

In what follows there will be presented the results of three sets of experiments which teach lessons on three points.

First. The influence exerted on the flow of water by a channel which is nearly straight and nearly uniform.

Second. The influence exerted on the flow of water by lack of uniform surface in a channel, the channel in question having openings along its course through which, however, water did not flow. The channel was otherwise uniform and straight.

Third. The influence exerted on flow of water by a slight lack of being straight, and by lack of uniform surface.

In all these channels the inclinations were nearly uniform, or at least were so small that their variations from uniformity could not have been determined. Although the inclinations were very small, they were measured over such long distances as to insure a desirable approximation to accuracy.

The experiments were made in the main channels for the water supply and river purification of Chicago. They were conducted by Mr. S. G. Artingstall, C. E., at present city engineer of Chicago, and published by him in the *American Engineer*, May, 1880. He also called attention to their peculiar indications, as described below, and measured them in a somewhat different manner and for an entirely different purpose.

The discussion of the experiments will be made in the logical order of their salient features as follows:

Chicago takes its water supply from Lake Michigan, through two nearly circular brick conduits or tunnels. Both of them extend out two miles under the lake in its clay bed. They take water from the lake through shafts and deliver it at the shore through shafts. One of the conduits has a vertical diameter of 5 feet 2 inches, and a horizontal diameter of 5 feet. The other conduit runs very close to this one. It has a vertical diameter of 7 feet 2 inches and a horizontal diameter of 7 feet. The five (5) feet conduit terminates at its shore shaft, and has a length of 2 miles and is straight. It also has a *uniform surface.* The seven (7) feet conduit, after reaching its shore shaft, continues in a straight line for 20,000 feet to the western part of the city. The portion of it along side of the five (5) feet conduit is straight and has a uniform surface, but no experiments were made on flow in it. Its land end, 20,000 feet long, in which experiments were made, is straight, but its top is perforated by a number of shafts through which water does not flow. *Its surface is, therefore, not uniform.*

Chicago has also a brick conduit, or tunnel, about two miles long, connecting Lake Michigan with the north branch of the Chicago River. Water is pumped through it from the lake to the river for the purpose of flushing the latter. This conduit is circular, and has a diameter of 12 feet. *In plan it is straight, but in vertical longitudinal section it is slightly sinuous. Its surface, being perforated at the top by a number of shafts, is not uniform.*

All of these channels were constructed under the same supervision, and have as near as practicable the same construction of surface, namely, first-class brick-work.

Diagram (1) shows longitudinal sections of the seven (7) feet and twelve (12) feet conduits, taken from the First Annual Report of the Chicago

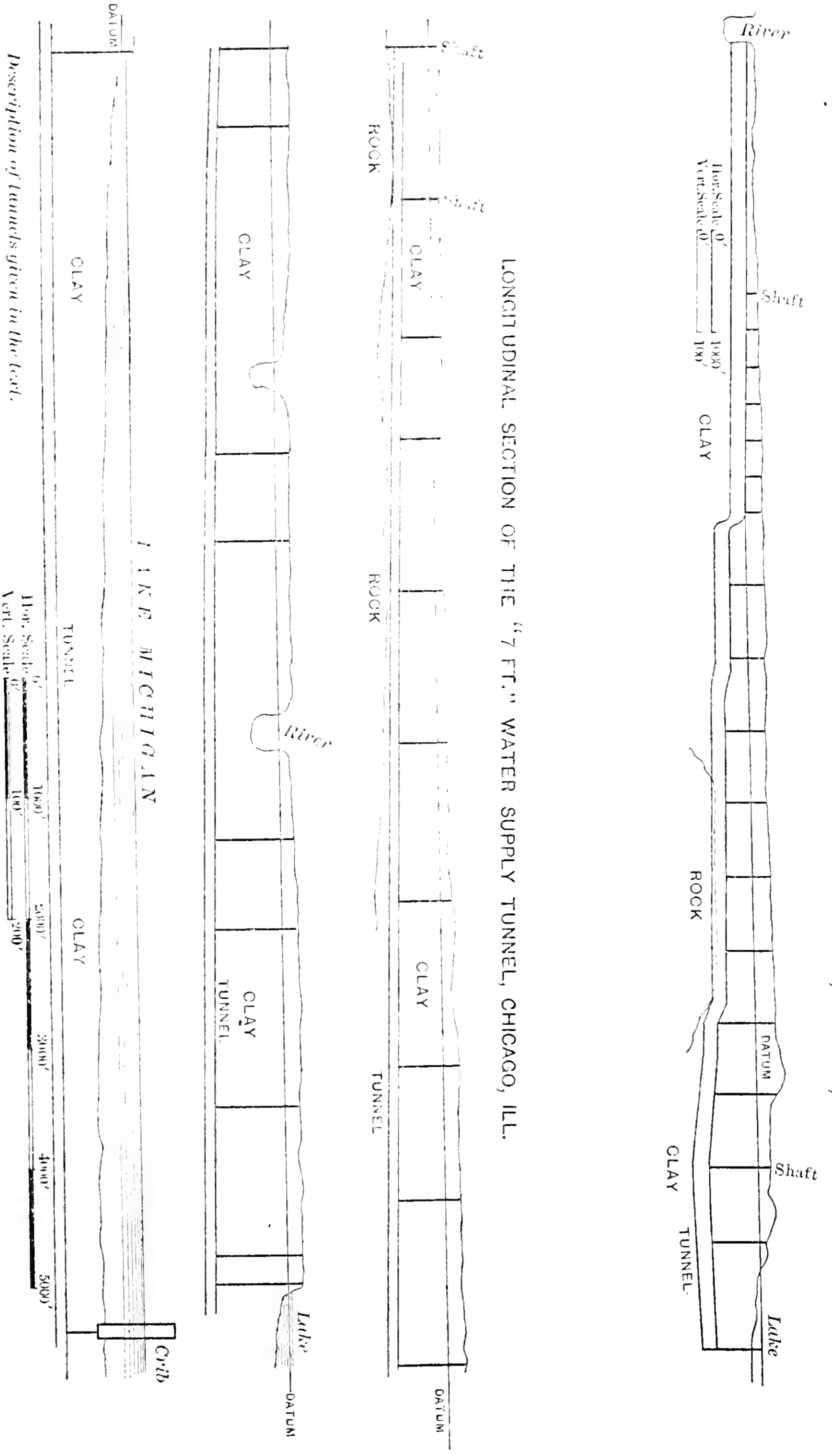


Diagram 1.

Department of Public Works, 1876. The lower section of the seven (7) feet water supply tunnel answers for a section of the five (5) feet tunnel, as both run side by side as closely as safety would permit in construction. The vertical lines show the location and number of the shafts. The shafts in the seven (7) feet tunnel answer the purpose of fire cisterns. Those in

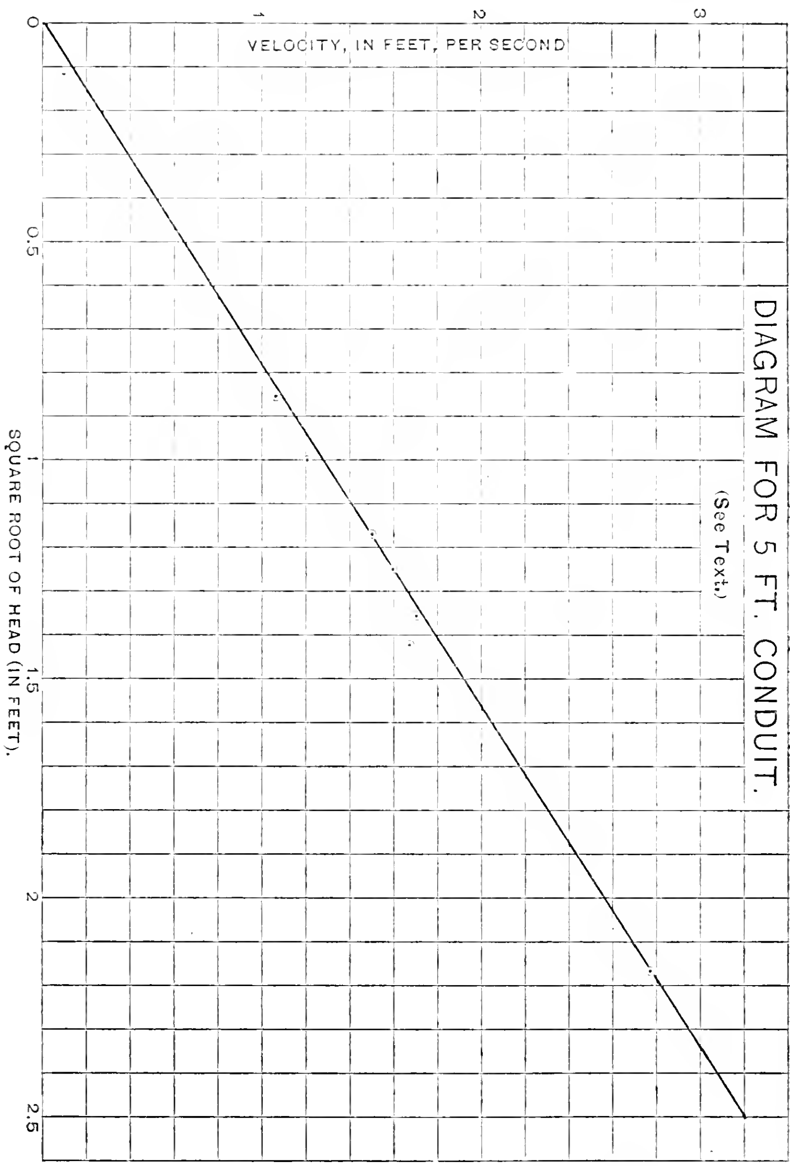


Diagram 2.

the twelve (12) feet tunnel were left open with a view to connecting sewers with them.

The method of conducting the experiments is described in great detail in the number of the *American Engineer* above referred to, and will not be repeated here, because it is only their teachings that are in question. This description of the experiments and the authority given will be allowed to stand sponsor for them. The writer has no doubt of their accuracy.

It is easy to see, from the nature of the construction of the conduits,

that they can be operated under varying heads or inclinations. And so it happened that the experiments were made under such conditions A number of experiments were made, in several instances, under each particular condition of head. They do not differ much among themselves, as may be seen by consulting the original records, and they have

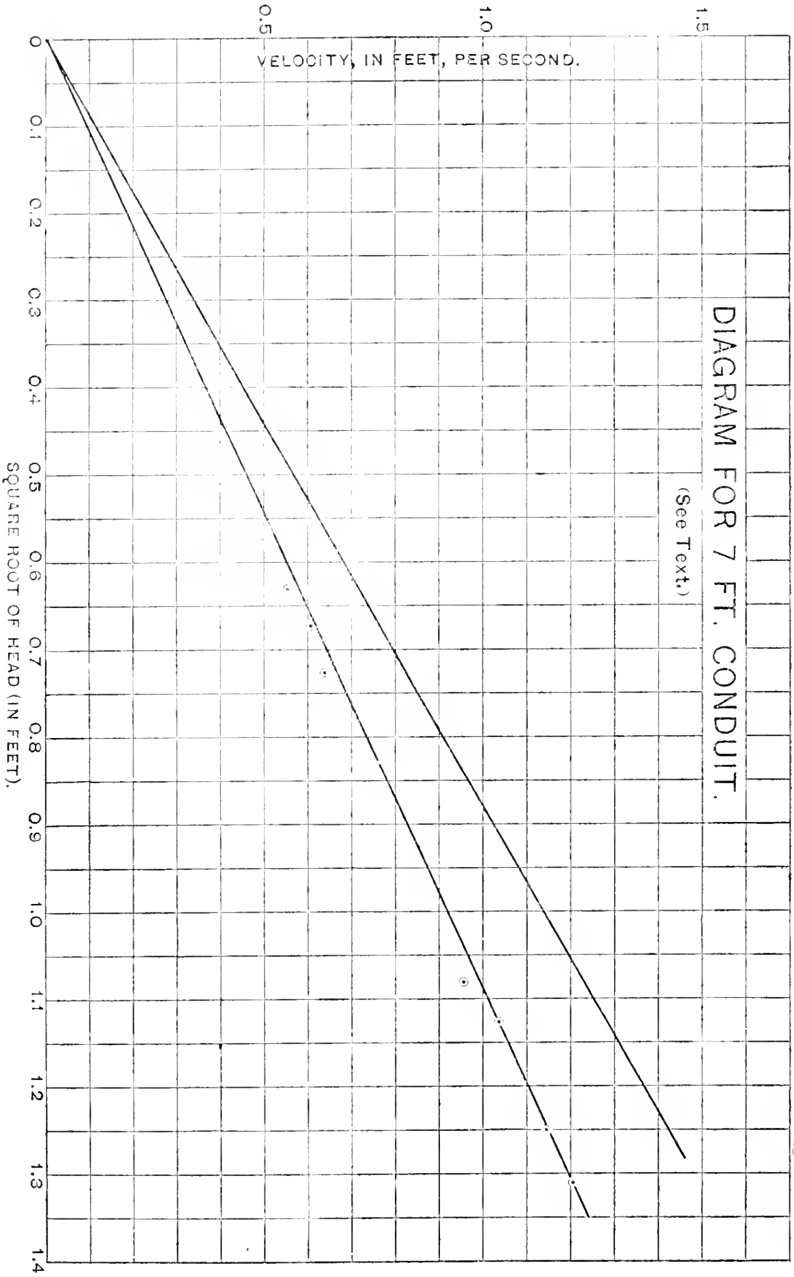


Diagram 3.

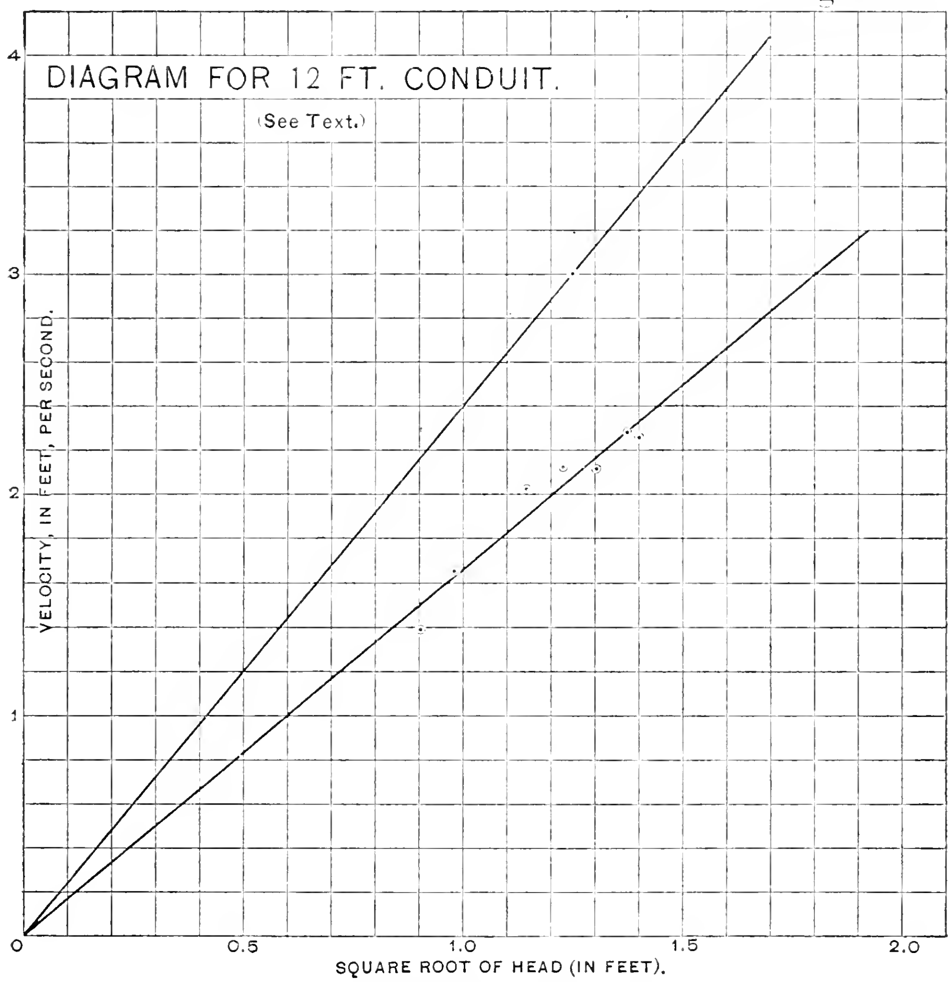
been combined for each head. The appended table gives the number of combined experiments, together with the head, mean velocity, and square root of head for each experiment. Also the length, diameter and hydraulic radius of the conduits.

The results have been plotted in diagrams 2, 3 and 4, which will be described in their order.

On diagram 2 the results for the five feet conduit are plotted. The ordinates are the observed mean velocities, and the abscissæ are the square roots of the corresponding heads. The small rings inclose the observed points. The straight line drawn among them represents the way in which the velocities varied with the square roots of head. The equation of the straight line is

$$(\text{vel}) = 1.283\ (\text{head})^{\frac{1}{2}}$$

Diagram 4.



The length and mean hydraulic radius of the conduit is given in the table. Introducing them into the equation, there results

$$v = 117\sqrt{rs}$$

Diagram 3 shows the results for the seven feet conduit, plotted in the same manner as diagram 2.

The equation of the straight line among the small rings, reduced to the Chezy form as above, is

$$v = 98.47\sqrt{rs}$$

Diagram 4 shows the results for the twelve feet conduit in the same manner as in the other diagrams, and the resulting equation is:

$$v = 91.1\sqrt{rs}.$$

The results are compared in the following table :

Conduit.	Equation.	Condition.
5 ft.	$v = 117 \sqrt{rs}$	Uniform surface.
7 ft.	$v = 98.47 \sqrt{rs}$	Straight, but surface not uniform.
12 ft.	$v = 91.1 \sqrt{rs}$	Straight in plan, but slightly sinuous in vertical longitudinal sections, and surface not uniform.

This table shows that the co-efficient of the formula actually diminished as the size of the conduit increased, which is a result contrary to experience in channels of this kind, of different sizes and of uniform surface and alignment. This is proved by the second step of advance in knowledge of flow in channels previously stated. The only way to account for the results is by the lack of uniformity of surface, and in the case of the twelve-foot conduit by slight lack of being straight.

On diagrams 3 and 4 straight lines have been drawn which do not pass among the small rings. These lines represent what might be anticipated if the channels had uniform surfaces and uniform alignment. They have been derived from a comparison of the results of the five feet conduit experiments with experiments by Darcy and Bazin in brick, cement and gravel channels, and with those of Ftely and Stearns in the Sudbury conduit. The method of this comparison is shown in the appendix hereto. Essentially the same results would flow from the well-known Kutter formula, though *for this particular case* the writer believes the following formula, derived as shown in the appendix, to be better:

$$v = 113.4\, r^{0.63} s^{\frac{1}{2}}$$

The following table gives the comparison of what might thus have been anticipated for uniform conditions with what occurred under existing conditions. The comparison is made by use of the Chezy form of formula, and the co-efficients speak for themselves :

Conduit.	Actual result.	Anticipated result.	Excess of anticipated result over actual result.
5 ft.	$v = 117 \sqrt{rs}$	$v = 117 \sqrt{rs}$	0 per cent.
7 ft.	$v = 98.47 \sqrt{rs}$	$v = 122.3 \sqrt{rs}$	24 per cent.
12 ft.	$v = 91.1 \sqrt{rs}$	$v = 130.5 \sqrt{rs}$	43 per cent.

It is thus seen that, for the seven feet conduit, a discharge 24 per cent. greater might have been anticipated, and it is believed that the lake end of this conduit does discharge water in such a measure. In the twelve feet conduit a discharge 43 per cent. greater might have been anticipated.

So much for the indications of these experiments as to the obstruction offered to flow by lack of uniform conditions in the channels, it being noted that the heads controlling flow were very small, and so more analagous to conditions that exist in natural streams than is ordinarily the case with experimental channels.

The writer has, in official reports and otherwise, furnished evidence to show that, when rivers overflow, much smaller velocities exist through given cross-sections than would be the case if flow took place through the same cross-sections with the overflow prevented. This condition was ascribed to the lack of uniform conditions of flow when the water was

flowing heterogeneously in and out over the flooded banks. The results of these conduit experiments are offered as an illustration of the effect of such a state of affairs.

It remains now to connect the results of the experiments with the question of floods in the Illinois River, providing constant discharge be added to it at all stages of the river, which discharge will amount to about five (5) times the ordinary low discharge, and to more than one-tenth of the high water discharge at the mouth of the river. It is an accepted fact among river engineers that, in rivers which flow through alluvial beds, when a constant discharge takes place through a considerable period of time the more shallow places become deeper and the deeper places correspondingly more shallow. That is, the channel changes in such a way as to approximate more nearly to uniformity. Again, it is the low water season that is the most enduring, and during that season a tendency in the same direction always exists, and the tendency will be stronger in a measure as the low water discharge is greater. Also, a similar tendency exists when the ratio of low water discharge to high water discharge is increased. Evidently all of these tendencies will be encouraged in the Illinois River by the added discharge, and consequently, when floods come, they will find a channel better adapted for discharging them than exists at present. The increased capacity of the channel for discharge under such conditions is due to the removal of obstructions to flow, and the consequent approximation to a uniform channel and uniform condition of flow. The existing conditions of flow in rivers, with their varying cross-section, is analagous to the condition in the water conduits not having a uniform surface.

The experiments in the water conduits are offered as a very simple illustration of how the capacity of a channel may be affected by irregularity, and, conversely, how it is possible to increase the capacity of a channel already obstructed by irregularities.

The principal irregularity in river channels is the variation of size and shape of cross-section from point to point, the shallow places being at the location of the bars. Everybody familiar with alluvial river beds knows the impossibility of deepening water on the bars by dredging, because new material soon takes the place of that removed. This would be different, if, at the time of dredging, the discharge of the river be permanently increased. It follows then, that the natural process of deepening water on bars by permanently increasing the discharge may be aided by dredging. In the Illinois River the bars are mainly at the mouths of tributaries, which bring in material that the now sluggish current cannot remove. With the discharge permanently increased the current will have more power to remove these deposits, and a more capacious channel will result. Or, if the deposits are removed, it will have more power to keep them from forming again. Thus there is more probability of increasing the capacity of the Illinois River in the manner suggested than if the bars were the result of the forces in the main river shaping its bed in a manner consistent with approximate stability.

If the average high water cross-section of the Illinois River in its central part be taken to be 800 feet wide, with a mean depth of 28 feet and a mean velocity of 2½ feet per second, no essential error will be made. This

will give a high water discharge of 56,000 cubic feet per second. If this discharge can be made to take place at a velocity ten per cent. greater than 2½ feet, or at 2¾ feet per second, the area demanded for its passage will be so diminished that the elevation of high water will be reduced by a little more than 2½ feet. The increased discharge which it is proposed to put in the river will not, at high water, raise the river as much as 2½ feet. Therefore, if the action of this permanently increased discharge be enough to increase the capacity of the river by 10 per cent., its effect will actually be to reduce flood height.

It does not follow, therefore, that the permanent increase of the discharge of the river will necessitate a raising of its banks to restrain flood waters. On the contrary, flood elevations may actually be reduced. The length of this paper does not permit discussing the possible increase of capacity of the river by simply deepening the more shallow places, but the writer will state that it will exceed many fold the percentage just stated as being sufficient to actually reduce flood heights with the permanent increase of discharge contemplated. No doubt a more full and complete discussion of the subject will find its way into the future reports that will have to be made concerning this great water way.

Table of data referred to in the above :

5 Feet Conduit.

No.	Head. in ft.	Vel. in ft. per sec.	$\sqrt{\text{Head.}}$	
1	0.716	1.073	0.846	Length = 10,567 feet.
2	1.009	1.211	1.004	
3	1.367	1.506	1.169	Area = 20.3 sq. ft.
4	1.548	1.593	1.244	
5	1.823	1.716	1.350	r = 1.27
6	2.012	1.689	1.419	
7	4.679	2.780	2.163	$\sqrt{r}$ = 1.127

7 Feet Conduit.

No.	Head. in ft.	Vel. in ft. per sec.	$\sqrt{\text{Head.}}$	
1	0.332	0.497	0.576	Length = 20,500 feet.
2	0.403	0.558	0.635	
3	0.456	0.603	0.675	Area = 39.4 sq. ft.
4	0.524	0.630	0.724	
5	1.174	0.957	1.084	r = 1.77
6	1.274	1.033	1.129	
7	1.567	1.143	1.252	$\sqrt{r}$ = 1.33
8	1.721	1.206	1.312	

12 Feet Conduit.

No.	Head. in ft.	Vel. in ft. per sec.	$\sqrt{\text{Head.}}$	
1	0.820	1.394	0.906	
2	0.967	1.662	0.983	Length = 8,900 feet.
3	1.321	2.025	1.149	
4	1.525	2.131	1.235	Area — 113.1 sq. ft.
5	1.697	2.141	1.303	
6	1.962	2.256	1.401	r = 3.
				$\sqrt{r}$ = 1.732

APPENDIX.

There has been plotted on diagram 5 the results of the Sudbury experiments, the Darcy and Bazin experiments in brick channels and pure cement channels, and the experiments in the five-foot Chicago conduit.

The process was as follows : Excepting in the case of the Chicago conduit, the experiments were made with varying values of hydraulic radius, while in all the experiments, Chicago included, the velocity was allowed to vary. The common logarithms of the hydraulic radii of the

channels have been taken as ordinates, and the differences of the common logarithms of velocity and one-half the common logarithms of slope are abscissæ. Straight lines have been drawn among the observed points, as shown on the diagram. The equation of the line passing through the point corresponding to the Chicago experiments is

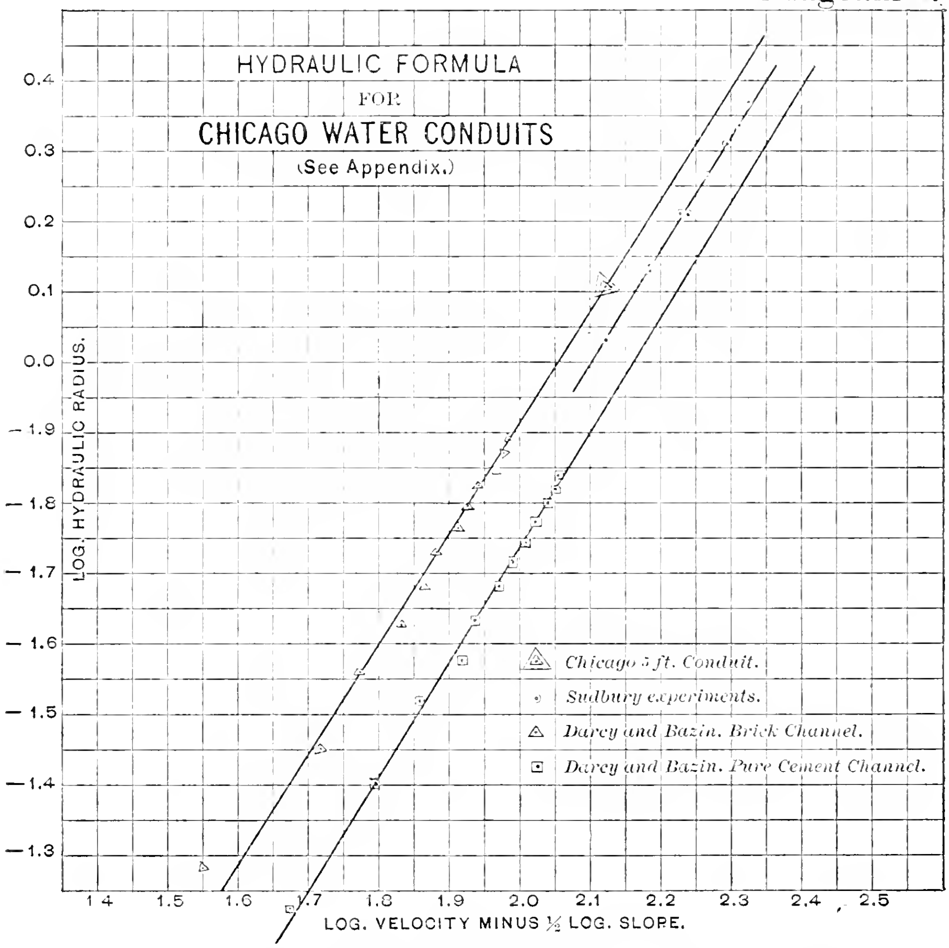
$$\log. v - \tfrac{1}{2} \log. s = 0.63 \log. r + 2.05476.$$

The intercept being a logarithm, it follows that—

$$v = 113.4\, r^{0.63} s^{1/2},$$

as given in the text.

Diagram 5.



Different persons might draw the straight lines a little different, but it is easy to see that no essential change could reasonably be made.

The values of the logarithms of hydraulic radius for both the seven-foot and the twelve-foot conduit would plot on the diagram. The elements governing flow in these conduits do not, therefore, differ greatly from what existed in the Sudbury conduit, so that it cannot be said that the formula given has been applied to cases much beyond the range of experimental determination.

NOTE 1.—The measurements of the hydraulic elements of the water conduits discussed in this paper were made as follows :

Head.—In the cases of all the conduits, they were first filled with

water, and the levels of the water in the shafts at the extremities were taken to be the same. These determinations were carefully made, especially in the case of the seven feet conduit, in which hook gauges in the extreme shafts were read every five minutes for six hours. The distances over which head was measured were 10,567 feet in the five (5) feet conduit, 20,500 feet in the seven feet conduit, and 8,900 feet in the twelve feet conduit. These great distances enabled the accurate determination of even the smallest head.

Velocity.—The velocities in the five feet conduits were measured by use of a current meter. Several years after these measurements were made the indications of the formula for this conduit were compared with weir measurements, a duty test of a pump being made. The results agreed within a percentage very small compared with the percentages involved in this paper.

In the case of the seven feet conduit, the discharge was measured, with unusual care, by a weir, and the velocity obtained by dividing the discharge by area.

In the case of the twelve feet conduit the velocities were measured by a current meter in different parts of the cross-section. The meter was used in a shaft. The surface of the conduit past the shaft was made continuous by the use of lagging, apertures being left only large enough for the insertion of the meter.

Area.—All the conduits were constructed under a continuous inspection in accordance with specifications which called for the areas given in the body of this paper.

The measurements given in the case of the seven feet conduit are the results of a third set of experiments. Those in charge of the conduit doubted the first two sets, and in having the third set made every attention was paid to eliminating possible sources of error. The indications of all three sets were, however, identical. Very few examples of hydraulic observations made with equal care can be found anywhere.

The percentages of error in the cases of any of the measurements used may safely be said to be very small compared with the percentages given in the body of the paper.

NOTE 2.—The number and dimensions of the shafts to the conduits are as follows :

Five feet conduit, none.

Seven feet conduit, 9 shafts, 8 feet diameter.
" " " 8 " 6 "

Twelve feet conduit, 16 shafts, 6 feet diameter.
" " 2 " 12 "

DISCUSSION BY J. B. JOHNSON.

It seems to me this paper hardly fits the title. So far as the paper is of interest to engineers it should be entitled : " The Effect of Sudden Enlargements in Masonry Conduits on the Flow of Water through Them, with Certain Hypothetical Inferences." As such it has considerable interest and value to hydraulic engineers. Probably never before has the influence of such openings been so well determined on so large a scale. I am inclined to admit the full force of the facts and conclusions, so far as

artificial conduits are concerned. It is only with the inferential part of the paper that I am dissatisfied. The writer states that "the existing conditions of flow in rivers, with their varying cross-section, is analogous to the condition in the water conduits not having a uniform surface." This I do not admit.' The shafts on the conduits were *sudden* enlargements, with angular corners. In rivers the changes of section are very gradual, and by gentle curves. All hydraulic engineers know that no analogy may be drawn between these two conditions. Thus in Fig. 1 there is a sudden enlargement from the area A_1 to the area A_2,

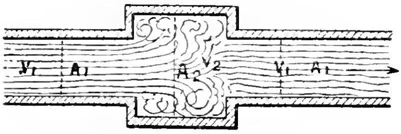


FIG. 1.

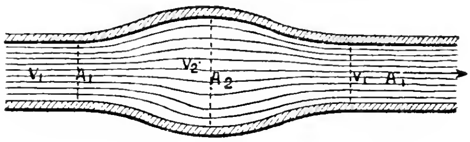


FIG. 2.

and as a result the mean velocity is reduced from V_1 to V_2, where $\frac{V_2}{V_1} = \frac{A_1}{A_2}$. In this case it is found by experiment that there is no equivalent gain in head at A_2, an amount of energy equal to $W \frac{V_1^2 - V_2^2}{2g}$ where W is the weight of the water passing in a given time, having been consumed in internal friction. If the enlargement had been gradual, however, as in Fig. 2, the static head in the enlarged portion would have been increased by an amount equal to $\frac{V^2 - V_2^2}{2g}$ and this increased head would have been utilized in generating the velocity V_1 again as the water passed back into the small section. There would thus have been no loss of head due to the enlargement. Now, Fig. 1 represents the conditions found on the Chicago conduits, and Fig. 2 represents the conditions found on all natural streams flowing in alluvial, sandy, or gravelly beds, and since there is *known* to be no analogy between the two cases here shown, I do not think it rational to *assume* one between the Chicago conduits and the Illinois River.

With reference to the flow over the banks in time of flood, the phenomena are very complex, and the conditions are never duplicated, so that any analogy between two overflowing rivers is hardly admissible, much less an analogy between any particular stream in time of flood and a masonry conduit, flowing under a head, having sudden enlargements consisting of vertical shafts. For the idle amusement of the curious such analogies might be drawn ; but, as a basis of engineering estimates and quantitative prediction, I can but regard such arguments as worse than useless.

Any increase in the low-water discharge will always prove more or less efficient in removing the sand bars from any natural channel, but if these bars are gravel bars, built up in time of high water, or thrown

out from a tributary during a local rise in that stream, as I understand most of the Illinois River bars to be, then the energy of the low-water flow, even when increased in the manner proposed, is not likely to accomplish much toward their removal. And even though they were removed by dredging, what is to hinder the next high water, or the next local flood in a tributary from doing again what it has always done before? Evidently there can be no great benefit resulting from an increased low-water discharge in the way of bar removal, or the maintenance of an improved channel, unless the materials composing the bed of the stream are such as can be moved by the stream at low stage. The paper gives us no light on this point, but I understand that the troublesome bars are all coarse gravel bars, on which the river at low stages has no influence.

I therefore conclude that the Chicago experiments cited, although valuable in themselves, have no rational bearing on the problem stated as the title of this paper, and furthermore that the proposed addition to the low-water discharge is not likely to have very much influence in the matter of bar removal and the lowering of the flood stages on the Illinois River. I would be inclined to think that unless artificial means are continually resorted to for the removal of the bars the volume of water added from Lake Michigan would practically be superposed on any flood reaching the Illinois River from its natural drainage basin.

DISCUSSION BY JAMES A. SEDDON.

I wish to say at the beginning that I substantially agree with Mr. T. T. Johnston in his main conclusions, and that, therefore, I should probably not have entered into a discussion of this paper, had it not met with some unfavorable criticism when read before the St. Louis Engineers' Club.

The paper covers two questions: First, conclusions from the data of the Chicago lake conduits; second, the question of the effect on flood heights of a constant addition to the discharge to the Illinois River.

To the first question I would give a qualified agreement. Mr. Johnston has presented the data and pointed out clearly that, in this case, mean velocity changed in a way directly opposed to its well recognized law for uniform channels, with nothing in sight in one case to account for this but a lack of uniformity of surface (shafts in the top through which water did not flow) of a kind that, I believe, has hitherto been considered immaterial, and the same in a second case combined with an imperfect alignment, which is generally admitted as material in its effect. I think he is, therefore, entitled to the credit of raising the question whether a lack of uniformity, of the kind noted, may not be a more material resistance to flow than has been supposed. I suppose that there are few engineers that would be ready to accept it as more than a question fairly raised, for out of the possibilities, taking an example that was well pointed out by Mr. Holman in the discussion before the St. Louis Club, the fact that the fall was taken only at the two ends and there was not absolute certainty that the hydraulic grade was without break, must throw some doubt on the conclusions.

The unknown, however, is a broad field in the velocity variations of

large discharges, and I think it a decided advantage that this question has been raised, and that Mr. Johnston has shown the courage of his convictions, and assigned approximately quantitative values to these effects ; the confirmation or disproof will now probably follow from data that have come, or will come, under the observation of hydraulic engineers. Personally, while doubtful of an effect so large as that suggested, I should not be surprised to find further investigation showing it a cause of quite material effects.

The second conclusion in regard to flood heights in the Illinois River, if rested on the first, has, of course, a very imperfect foundation ; for not only would the explanation of the Chicago conduit data be in question, but the lack of uniformity found in river channels is too different in kind and in scale from that found in the case cited, to admit of an unquestioned transfer of conclusions from one case to the other. This, however, I take it, was by no means Mr. Johnston's intention, but writing as he can only do on this question for those familiar with river hydraulics, he has presented this case as an interesting parallel to phenomena observed in rivers, and then passed on to the question of the Illinois River, resting his conclusions there on a much broader field of experience, and only tracing the outlines of theories with which he assumes familiarity. In his conclusions here I most heartily agree with him.

Not to extend this beyond the range of a short discussion, I may say that I think there is no well considered theory, based on data of our Western rivers, that would lead us to the conclusion that the addition of a constant discharge to an alluvial river, and the resulting diminution of the ratio of high to low water volume, would work in any way but as a permanent benefit. In an admirable paper on the relation of sections by Mr. McMath, presented in Rept. Miss. Com., 1881, and further discussions by him of the levee problem for the lower Mississippi, read before the St. Louis Engineers' Club, he reaches the conclusion that velocities up to a stage intermediate between high and low water operate to produce lower gauge heights for a given value of discharge, while beyond this critical stage they operate to produce higher gauge heights. Differing from Mr. McMath in his conclusions on the effects of high water velocities, except after overflow, Mr. Johnston, in an extended study of the variations of discharge with gauge heights in the Missouri and Upper and Lower Mississippi rivers, came to substantially the same conclusion in regard to the effects of low-water velocities ; this effect of the low-water velocities is reasonable then on the basis of theoretic consideration, and more, it may be traced as an actual fact in data collected. It needs but the statement therefore that velocity increases theoretically faster with gauge heights at the lower stages, and practically on the Mississippi and Missouri rivers in about a constant ratio, while gauge heights increase for a given change of discharge very much less at the high stages than the low, to see that, accepting the conclusions above, the action of those forces that are lowering the gauge heights, in the changed conditions of the case in question, are increased in a much larger proportion and act through a longer time than those that may be opposed to change in this direction.

Or simply considering that the height of bars in the present river is in approximate balance with present forces, we may fairly conclude that the new balance, in the changed conditions, will be a lowering along the whole river. Of course, before quantitative results could be assigned, the problem of the particular river would require special study, but that the addition of a constant discharge that would increase the ordinary low-water volume five times might be expected to decrease the high-water gauge height at least two and a half feet seems to me altogether reasonable.

Dropping special considerations, it is difficult for me to conceive of how any one familiar with river data can feel satisfied that an alluvial river whose low-water volume was permanently increased to five times its original value, and its high-water volume only about one-tenth, should remain permanent after this change, as a river of higher slope than in its previous condition, and that is the alternative, if Mr. Johnston's conclusions are not accepted, for the elevation at the mouth of the river is about fixed by the elevation of the Mississippi.

Though the bed of an alluvial river is generally recognized as approaching a state of equilibrium between the forces of flow acting on it and the ability of the material to resist those forces by its stability, still, in the case of bars of long standing, the material may settle so as to have a power of resistance materially beyond the equilibrium under which it was placed by the flow. In this case, as pointed out by Mr. Johnston, the engineer recognizes that, while the regimen of the river remains the same, the artificial removal of the bar is of no benefit, since it is quickly replaced in the same or a slightly different location by the operation of its original causes. But in case a more favorable regimen has been established, and some of the bars are found not answering to the changed forces, then their artificial removal is attended with permanent benefit. Mr. Johnston has, therefore, pointed out the possibility that some dredging would be needed.

In this connection, I may state that for some years it has been a favorite idea of mine that the proper treatment of a case of this kind would be by a cheap arrangement for scraping the surface of the bar, allowing the greater part of the transportation of material to be done by the current. No amount of care could artificially do so exactly the right amount of excavation on the bar, or place the excavated material in so permanent and beneficial a position as the forces themselves, with whose action it must be ultimately in equilibrium.

Holding to the privileges of a discussion, I have only tried to touch on one or two of the points in this question; a thorough solution, I take it, will be required of those connected with the work, and as this, it appears, will have to be submitted to a legislative body, while the weight of much that they have to offer as evidence would only be appreciated by the specialist in river hydraulics, I feel very strongly that those whom experience and study in these lines have qualified for a fair appreciation of the question should, if they felt themselves called on to discuss it, consider the main point squarely on its merits; and the main point is, will not the addition of this constant discharge to the Illinois River produce a tendency to change in the bed which would allow larger discharges to pass at a given gauge height, than at present? It was admitted that this change might have to be assisted at first, by dredging, and that the

specific amount to be expected of this change can only be determined by special study.

In regard to a solution of this question that would carry conviction to those that might be called on to pass upon it, it has occurred to me, from some experimental investigation that I have attempted, that a very cheap series of experiments might help to set at rest any doubts that might exist as to the correctness of Mr. Johnston's conclusions. As pointed out in a paper of mine in the JOURNAL, February, 1886, we have discharge (Q) multiplied by fall (H) as the energy expended in a reach, and the equilibrium of river bed with the forces acting on it is expressed by an equation, $Q\,H = f$ (bed), we may, therefore, study with some confidence the general features of change of bed in a given material, in experiments with very small values of discharge and very large values of fall or slope. Unfortunately, quantitative values could not be reached this way from present knowledge, since as yet we are entirely in the dark as to what are equivalent dimensions between the large and small scales; also the experimental stream might have to be made to carry silt, and some trial required to determine approximately equivalent times for adjusting the variations of discharge; but such experiments are very cheaply and easily made, and when more generally undertaken in like questions, I believe will finally prove of great practical value.

But entirely beyond the present and the local problem, and the question of flood heights in the Illinois River, there is a broader field to which we must follow the effects of this work when completed. The final enlargement to a discharge of 15,000 cubic feet per second will add to the volume of the Mississippi an amount approximately equal to a river one-half the size of the Missouri at low water; such an addition to flood heights in a river as large as the Mississippi would be entirely immaterial, even if imposed on it (which would not be the case) as an additional elevation, since it would here amount to only two or three inches: its effect at low water, though, merits attention. If no change of bed were here effected, from data collected we could easily state the results of this addition to the volume as follows: Gauge heights higher, or depth on all bars greater at extreme low water by amounts approximately from one and a half to two feet above Cairo, and something over one foot below Cairo, as far down as serious obstructions to navigation are found. This in itself, I think, would be no immaterial benefit to navigation, but that the increased depth realized from this cause would be confined to these values, I think no one would claim; for, stated briefly, it is simply an addition to the present low-water energy of the river of an extra working force of more than 650,000 horse-power, largely concentrated upon the bars in some ratio to their obstruction, and employed there for several months during each year in helping to clear out low-water channels.

That more than double the values above stated might be expected as the finally realized additions to the low-water depths, I think is not too large an estimate; and this being the case, I see no reason why the whole Mississippi Valley, seeing that they have a good thing for the taking, should not want more of it.

TRACTION ROPE RAILWAYS.

By D. J. Miller, Member of the Western Society of Engineers.

[Read March 1, 1887.]

In the fall of 1882, I had the pleasure of presenting to this Society a brief description of the Chicago cable roads, and in said description advocated the introduction of duplicate cables, considering duplication of the motive power of vital importance to the perfection of this system of traction. Since then I have been able to carry my theory into practice to a certain extent, and have had the satisfaction of demonstrating the feasibility of what was at that time an untried plan.

Four years ago there were, in the United States, 36¼ miles of cable road in operation and under construction. January 1, 1887, there were 116 miles additional in operation and under construction, making a total of 152¼ miles, and from present indications it is fair to assume that at least 100 miles will be added to the above figure during the ensuing year.

While some of the later roads contain valuable inprovements, there are others the designs and workmanship of which could not well be worse. Within the last year or two, many unscrupulous speculators have manifested a decided interest and activity in cable work, attempting, especially of late, to palm off on the public what they are pleased to designate as some particular system of cable traction, the so-called system in reality containing not one element requisite to a good road; but this method of propulsion has grown in popularity so rapidly that many capitalists willingly invest in cable roads regardless of their merits or demerits. We have known of millions being expended in constructing lines which, when finished, were inferior to animal traction, so far as service to the public was concerned, and from a financial standpoint also, the horse road would be preferable. Nevertheless we do not know of one in operation not paying a fair interest on the first cost.

Unless investors exercise extreme caution, and closely investigate before absolutely committing themselves to any plans or schemes submitted for approval, the increasing number of inferior roads, together with bad management in operation, will result in arousing general indignation, and public sentiment will eventually bear strongly against their further extension and greatly interfere with future progress in this direction.

A street railway, under the cable system, becomes a colossal machine, and its efficiency is unquestionable, provided the component parts are properly arranged and cared for, but with disinterested and careless or ignorant attendance, demoralization and destruction must surely follow in the course of events.

The serviceableness of a road, no matter how meritorious the system, can and will be materially affected by mismanagement, which fact cannot be too forcibly impressed on stockholders, as in this case it means smaller dividends and costly repairs.

We find records of patents, both foreign and American, long since expired, the drawings and specifications of which cover the same ground that inventors of later date have endeavored to secure by letters patent.

For instance, in an English patent granted in 1845, a tube between the rails is illustrated with slot in centre and a rope to draw the car. The gripper was provided with movable parts for grasping the cable, and had wheels intended to move on rails or guides in the conduit.

The principles demonstrated in the above-mentioned patent are carried out in the roads of to-day.

To show the development forty years ago in cable traction, we give a few extracts from a description of the London & Blackhall Railway, published in 1852, a copy of which was kindly furnished us by Gen. Charles Fitzsimmons.

"A pair of powerful marine engines were erected at each end of the line, to which the drums for winding up the rope were connected by friction clutches. The drums were of cast iron, each twenty-three feet in diameter, and their circumference revolved on an average of twenty-six miles per hour. The rope was five and three-fourths inches in circumference and being upward of six miles in length, weighed about forty tons, and was sufficiently long to reach from one end of the line to the other, when somewhat more than one-half the rope was wound upon one of the drums. The cable was supported along the line by cast iron wheels or sheaves, three feet in diameter and seven and one-half inches in width, which not only prevented the rope from trailing upon the ground, but also guided it around the curved portions of the line. The carriages were connected to the rope in such a manner that they could be instantly released without stopping the motion of the rope, and again connected if required." In the foregoing we find the following points of interest: First, the cars could be detached from and again attached to the rope while the latter was in motion. Second, the cable moved at the rate of twenty-six miles per hour. Third, the winding drums were of sufficient capacity to store three miles of one and seven-eighths inch rope, weighing twenty tons. Fourth, these drums were connected to the engines by friction clutches.

As copies of foreign patents were not formerly filed in the United States Patent Office, it is probable that Gardner was not cognizant of the existence of a similar English patent, when he obtained the American patent in 1858 on the conduit and slot for traction rope railways.

In 1869 a patent was issued to Gen. G. T. Beauregard covering some minor details, but the drawings represented a grip having jaws that could close on a moving cable, and the friction caused by this contact would start the car as easily as might be desired. In this design, the cable was above the car.

Gardner's specifications refer to a grip (calling it a catch) connected to the car, projecting through the slot, and engaging with the cable in the conduit, and these inventions embodied the rudimental principles of the present system of traction rope railways. Forty-five patents on traction were issued in the United States prior to 1872. Of this number, four were granted to Mr. A. S. Hallidie of San Francisco, on running and carrying ropes, but were not applicable to the propulsion of street cars.

In 1872 Mr. Hallidie obtained his first patent on the grip, the drawings of which illustrated a vertical shank intended to extend from the floor of the car, through the slot and into the conduit, with wheels or jaws on

the lower end for gripping the cable, but the principal points were not covered in the patent.

In constructing the first cable road, Clay street Hill, San Francisco, the Gardner tube, and above described principles of the Hallidie grip, together with the Beauregard grip jaw were adopted, with modifications and improvements.

The second road constructed was on Sutter street, San Francisco, and this differed somewhat in detail from the line on Clay street hill. The general arrangement of the grip was considered so satisfactory that it was afterward adopted on nearly every road in San Francisco, and this grip, with other improvements, was designed by Mr. Asa E Hovey, the engineer of the road, who has for the past six years been connected with the Chicago roads.

To San Francisco belongs the credit of operating the first street surface cable road; yet Philadelphia, by the invention of Gardner, must be accredited with the tube or conduit. But beyond question the undertaking in Chicago was attended with the greatest risk, as it had always been supposed that such a road could not be successfully operated in a cold climate.

To Mr. Holmes we must concede great foresight, and to him the cable road owes advancement and superiority of construction as well. When the Chicago roads were projected, there were but sixteen miles of cable road in operation in the world, and during the year 1881, the lines constructed in the above-mentioned city were on a larger scale, and more improved in detail, than anything of the kind previously built.

From the beginning the evolution has been gradual, until we now have a system destined, doubtless, to entirely supersede animal traction, wherever the traffic will guarantee the necessary outlay.

While single rope roads can be, and are operated successfully, they are nevertheless not entirely satisfactory, owing to the frequent stoppage for repairs, whereby the public is greatly discommoded, not to mention the money loss of the railroad company, and to overcome this acknowledged defect we have duplicated the motive power throughout. All machinery must be especially designed for its work, and no detail neglected, as the operating expense of motive power is governed almost entirely by its arrangement, as is also the continuous running of the cars.

Machinery and cables cannot give as good service in constant use as when the necessary time can be devoted to inspection and repairs; and on single rope roads, the two or three hours available in the morning are not sufficient to thoroughly inspect the cable alone; while with the duplicate cables all cars can, at any time, be transferred to the second rope without interruption to traffic.

Considering the success of the duplicate system, and the great advantages secured by its adoption, we feel justified in giving a description of some of the principal details, showing how the ropes are worked independently.

At the point where the cable is first carried into the conduit, sheaves four feet in diameter (called elevating sheaves) are used to elevate the rope to a line where it may be received into the gripper. On single rope roads these sheaves are set on the line of slot, and grip guided

around said elevating sheaves, then brought to where cable is received by a very sharp reverse curve in slot and track rails, making an offset in the slot, of four and one-half inches in a length of less than five feet. As these short reverse curves are troublesome, I abandon them, placing the sheave in a frame having trunnions at the ends on which the wheel tilts.

This tilting is accomplished by a horizontal lever moving in a vertical plane and is operated by the grip as the car passes. The normal line of the elevating sheave is in the line of the travel of the grip, and as the car approaches the grip rides on a horizontal lever, which is depressed by the movement and weight of the grip, and in turn tilts the sheave. The grip then passes, the sheave resumes its former position and the cable is laid between the grip jaws. Machinery thus operated weighs several hundred pounds, and to manipulate it with safety every two or three minutes the year round, while the cable is moving 8 or 10 miles per hour, necessitates close calculation. To allow one second of time for the performance of the operation above described, a run of from 10 to 12 feet is indispensable, and for this reason the horizontal levers are about 10 feet long, for if the work were performed with 2 or 3-foot movement of the car, the contact of any metal bar with the grip would be as destructive as blows from a sledge-hammer. The cable having been thus received into the gripper at the starting point, is carried to the end of the line, passing freely through the grip jaws in bringing cars to a standstill. Reference will be made to the grip later on.

CONDUIT, PULLEY VAULTS AND DRAINAGE.

Complete drainage must be provided for conduit and vaults. In our experience the *débris* from the street passes through the slot, obstructing the free flow of water, and where carrying pulleys are placed in the main conduit water collects about the wheel. While this is objectionable in summer, it works untold damage to cable and wheels in severe winter weather. I have known of instances where a majority of the wheels have been totally ruined by an attempt to start and run the road after a short stoppage on a cold day. The wheels being stationary, the moving rope soon made sad havoc.

Where carrying pulleys are placed in main conduit, the wheels are necessarily small, conduit deep, and first cost of construction excessive. To avoid these objectionable features I introduced carrying pulley vaults, see Fig. 1, at intervals of 35 feet, giving ample space for pulleys of desired diameter, and also for the admission of a man having charge of said pulleys.

In excavating for structural work, a sewer-pipe is laid beneath the main conduit, from one pulley vault to the other, and the grade may be independent of that of the street. Outlets are provided where necessary, and are connected with street sewer if possible.

This system of drainage allows the unobstructed passage of water from the main conduit into the vaults, thence to the city sewers, thus securing perfect drainage for the entire road.

By adoption of the above-mentioned vaults, we are enabled to reduce the size of the main conduit to a depth of two feet, and a width of 15

inches at largest section, thereby materially reducing the first cost of construction.

The slot rail used allows the grip to be carried nearer the street surface than in any other system, and is formed with oval corners, preventing the fastening of horses' shoes, which are endangered by sharp cornered rails.

CARRYING PULLEYS.

In examining the working and condition of carrier pulleys on several cable roads, I concluded that there was room for improvement in their design, and also that the journal boxes for same were capable of betterment. A poorly balanced wheel will injure the cable and assist in its own destruction, and it is my opinion that there are roads on which the carrying pulleys alone cost more than the cable.

I have endeavored to design a pair of wheels sufficiently wide to prevent the rope from leaving same; also have them large and light enough to move slowly and easily on the journal boxes.

The carrying pulleys of this system are twenty-four inches in diameter over flanges, and six and one-half inch face. Each wheel weighs thirty-nine pounds independent of shaft. The journals are seven-eighths inch in diameter and three and one-half inches long, running in a composition box which was made up especially for the purpose. This metal, under the load and speed, has served with absolutely no attention for six months.

On the Tenth avenue cable road, in New York, there are upward of 1,900 carrying pulleys, half of them in constant operation for 22 hours a day.

Two men only, at $1.75 each, take entire charge of all wheels connected with the road, starting at one end of the line in the morning and arriving at the terminus at the close of the day. These men walk slowly over the route, listening to the running of pulleys as they pass same. Should they expose each pair of wheels there would be 950 covers, weighing 250 pounds apiece, for them to remove and replace, and at best not more than 40 could be examined in one day, consequently were it not for the afore-mentioned arrangement of boxes, men would be needed every few blocks on the avenue. This road has been in operation eighteen months, and the original wheels are still in use, several of which we have calipered, and find no perceptible wear.

With all this in their favor, we have to record one fault, and that is their resonance. The ringing sound has been distinguished for a distance of 200 feet when the street was perfectly quiet, and this can only be totally destroyed by lining the sheaves with a non-metallic substance, an expenditure hardly justifiable except on streets used exclusively for residence, as the noise is not particularly noticeable on a business thoroughfare.

CURVES. (SEE FIGS. 2 AND 3.)

The conduit is 3 feet deep on curves, and cables are carried around a different elevations, the line of inner rope being 14 inches and the outer 24 inches below grade. The horizontal wheels are 32 and 40 inches in diameter. The first or top wheel has a flat face, against which the grip takes bearing and thereby hinders the inner cable from leaving the grip

in case the car is stopped on the curve when the latter rope is in operation. This inner cable rests on or runs against the single groove sheave (represented in drawing) between the top flat-faced wheel and the lower conical wheel, and said conical wheel has a spiral groove for guiding the outer and lower rope (when in use) down to its proper line.

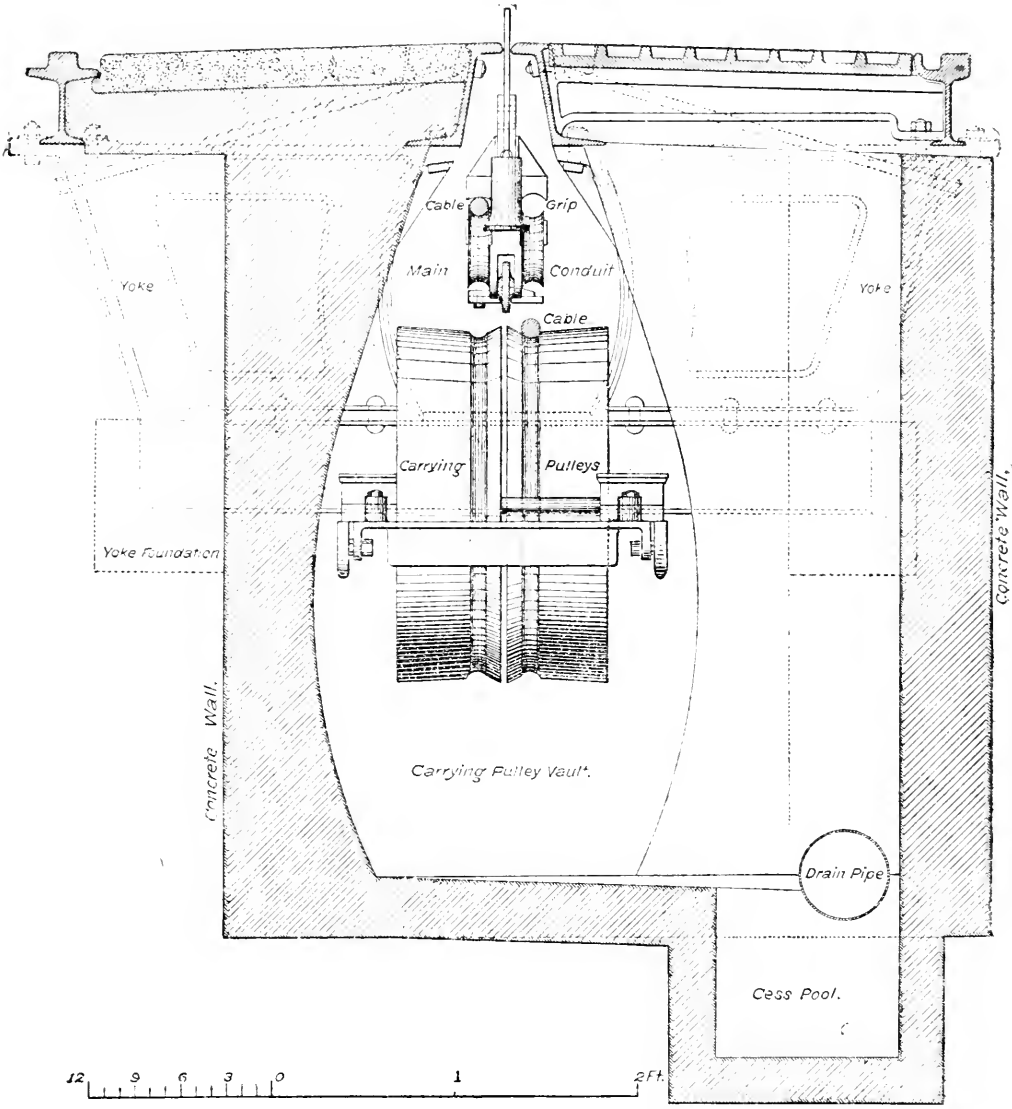


Fig. 1.—Traction Rope Railways.

Transverse sectional view of conduit at carrying pulley vault, showing pulleys in position. end view of grip. one cable in grip and the second rope resting on its supporting or carrying pulley.

after the grip has passed. These wheels are placed every 4 feet on sharp curves of, say, 40 or 50 feet radius, and at 8, 12 or 16 feet where there is less curvature.

The cast-iron riser of the yoke supports the street from the central slot to the concrete wall, a distance of 15 inches from the inner rail.

Cast brackets are placed immediately above the risers aforementioned, and support the cast-iron grating of the street, which extends the length of curve, presenting a uniform surface far superior to the usual paving.

MOTIVE POWER.

The building containing the motive power of the Tenth avenue cable road is situated on the east side of Tenth avenue, having a frontage of one block (two hundred feet). The plant consists of two twenty-eight by forty-eight Wright engines, arranged to be operated together or independently, as may be required. One continuous line of main shafting is used, transmitting power to four driving drums, each pair being connected by a system of gears, and power transmitted from the main shaft by friction clutches, which are composed of sixteen wrought-iron and steel plates, each three-eighths inch thick by four feet in diameter. These plates give sufficient area in square inches, so that the pressure applied to operate one rope will not force the lubricant from between their surfaces. The driving drums are ten and one-fourth inch face, with five grooves each, which are about twelve feet in diameter, the first groove on the first drum being the largest; the first groove on the second drum is one-eighth inch less in circumference than the first grove on the first drum, and all other grooves are reduced successively in the same ratio. Each pair of driving drums has an independent train of driving gears, and in the centre, between the drums, a pair of eight by eight upright engines are located. These are connected together and so arranged that they can be thrown in gear to operate the main drums.

To avoid accidents and stoppage of the road from stranding of the rope it is necessary to frequently examine the cable to keep it in perfect order To do this thoroughly, the rope should be detached from the main machinery and operated at a slow rate of speed. The service required of the auxiliary engines is to move the rope slowly for examination, run an old rope out and a new one in, or for any repairs necessary on the main machinery. The driving machinery being divided into 2 sets of 4 driving-drums each, and each set having the drums arranged in pairs, the auxiliary engines between same can be connected to operate either pair as may be desired. The cables are taken in around said drums and make 2 or 3 wraps, then pass to the tension wheel, which is on a car, and traverses a track in the rear of the driving machinery, then is carried out into the street again. With cables about 4 miles in length, they give a movement to the tension car of from 4 to 5 feet, making from 8 to 10 feet of rope to be disposed of every few minutes, thus continually moving the tension-car back and forth.

As the car with the wheel is quite heavy, its movement is not easily checked, and a quantity of rope is usually payed out and received into the building, which would not be the case if car were properly governed. This duplicate system has been provided with an automatic variable tension, decreasing or increasing the tensile strain on the traction rope as the circumstances may require.

CABLES.

Each cable for the Tenth avenue road was manufactured complete in one piece and shipped to 128 street and Tenth avenue, mounted on a single reel, which with cable weighed 94,000 pounds.

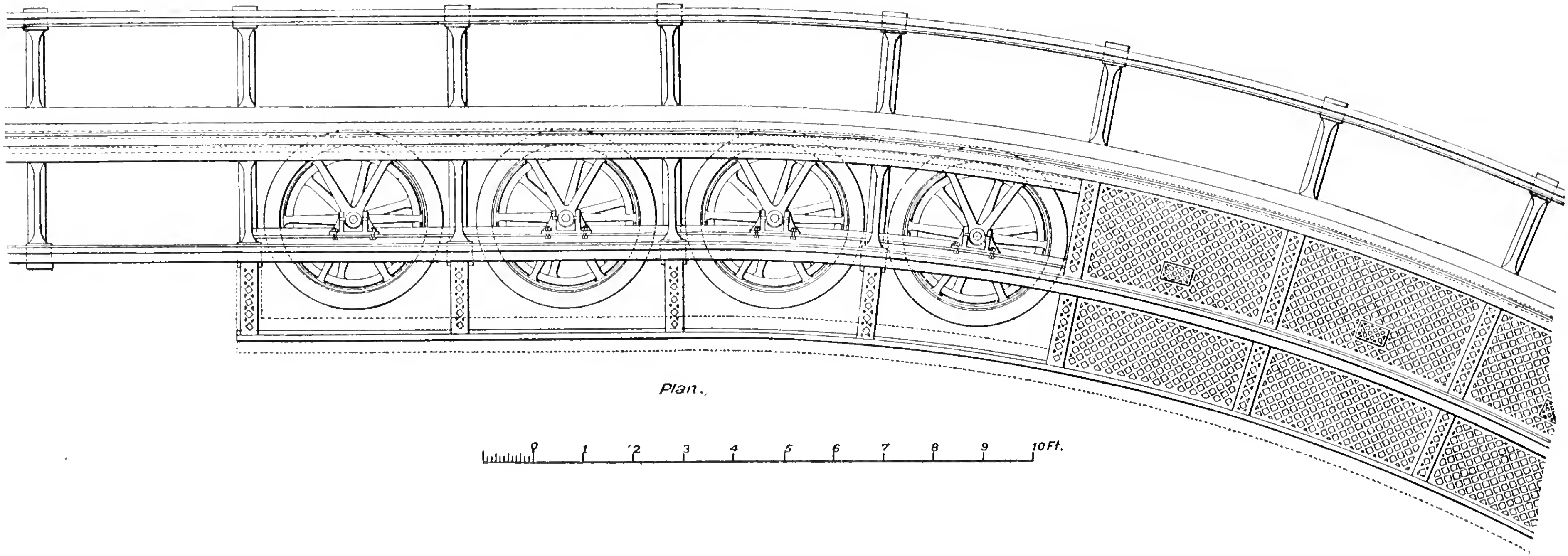


Fig. 2.—Traction Rope Railways.

Plan on curve.

Cables used on the majority of roads are composed of six strands, each strand having nineteen wires, seven of them forming the heart, around which the remaining twelve are wrapped ; and these latter receive all the wear. One of the Tenth avenue cables has seven small and nine larger outer wires, while the second rope is composed of nine small inner wires with ten larger outside wires. This change in the size of wires was made by the rope manufacturers as an experiment.

For every mile of single track there are over one hundred and fifty carrying pulleys, and on a road running ten miles per hour for 24 hours the cable will pass over thirty-six thousand carrying pulleys each day ; there are also horizontal wheels on curves, and several large sheaves in wheel vaults, and should any number of the above be out of order the cable must be seriously injured.

ESTIMATE COST OF CABLE ROADS.

Many inquiries have been made concerning the cost of a good cable road, and the operating expenses of the same. We give below some information on this subject, and although the different items are not detailed, the figures are sufficiently accurate for the purpose. The estimate is for 2½ miles, everything included :

2½ miles road-bed complete, paving included	$319,000
Plant, including real estate, buildings and motive power complete	113,500
Rolling stock	70,000
	$502,500
Add 10 per cent. for miscellaneous expenses	50,250
Giving total cost of road and equipment	$552,750
Operating expenses per year, $102,953. To this add interest at 5 per cent. on first cost of road, say $600,000, $30,000, making total operating expense	132,953

This would require a traffic of 2,659,060 per annum. The excursion traffic being a large item with all cable roads, we will therefore allow 25 days during the year in which 20,000 passengers will be carried, making 500,000, leaving 2,159,060 passengers to be carried in the remaining 340 days, which gives us 6,350 passengers per diem.

If 75 per cent. of this number, or 2,000 per mile per day, can be calculated on with a horse road, it will be perfectly safe to invest in the cable system owing to the increase.

As the above is for 2½ miles, one mile of road will cost $221,100. By multiplying the latter figure by the number of miles desired to build, a close and reliable estimate will be obtained. The foregoing covers real estate, buildings and equipment. Operating expense covers officers' salaries, pay of employés, taxes, and in fact every item of expense connected with the operation of the road.

It must be borne in mind that the estimate given above covers the expense of making 435 round trips every 24 hours.

To perform this work with animal traction would require 272 horses on a comparatively level road, which would cost annually for maintenance and renewals	$59,568
The operating expenses of the motive power with the cable system	26,640
Showing saving annually effected	$32,928

The estimate on cost, and also operating expenses, are liberal, but the minimum number of horses have been considered. With animal trac-

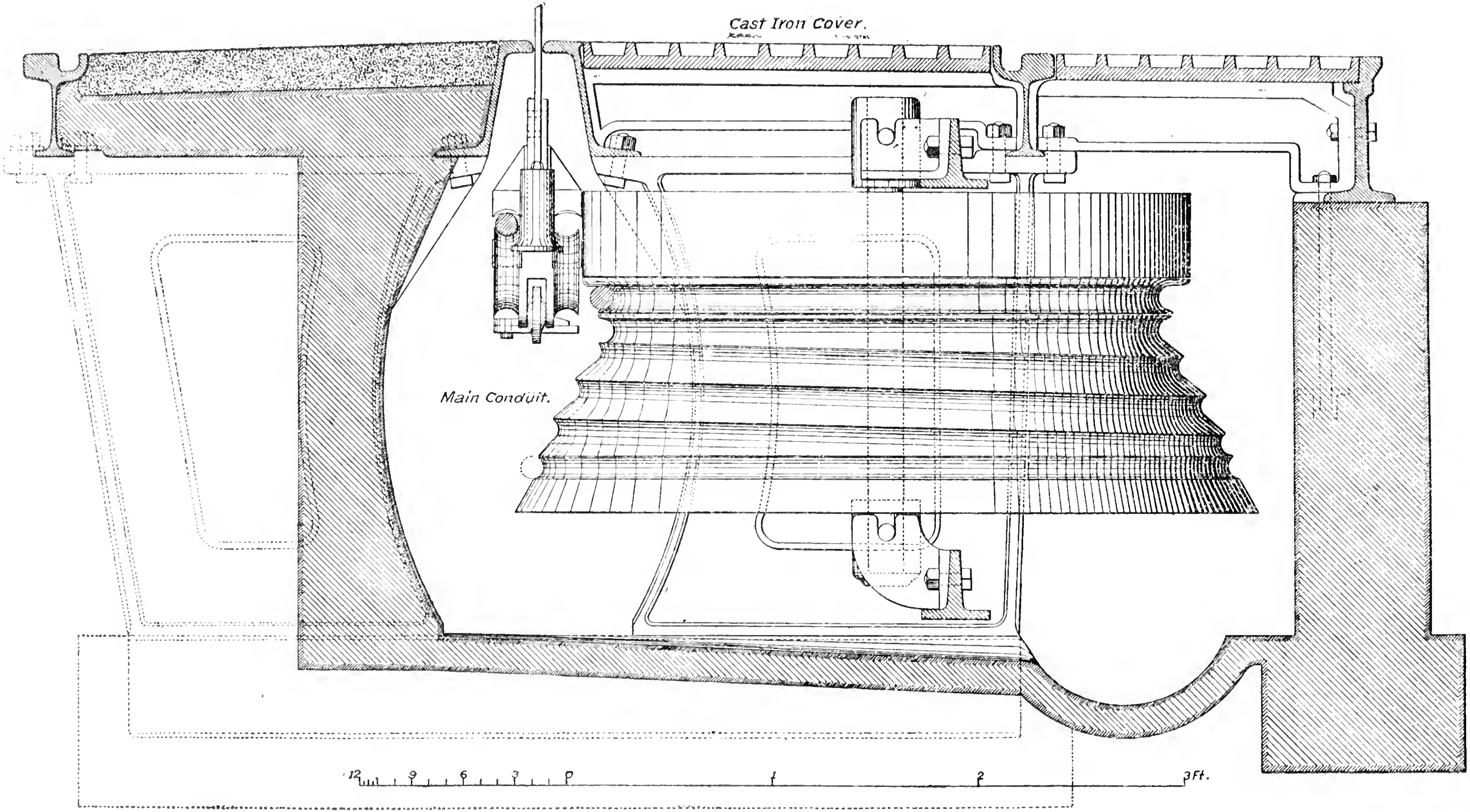


Fig. 3.—Traction Rope Railways.

Transverse section at curve, showing horizontal wheels in position and end view of grip.

tion, there could be no sudden expansion of the carrying capacity; but with a road such as described above it is only necessary for a railroad company to have adequate rolling stock and they are prepared for any emergency. There is no other system of traction that can so readily respond to the demand of traffic for increased accommodation.

Two passenger cars can be attached to a single grip-car and carry, easily, 125 passengers. And by supplying cars sufficient to despatch one train every minute a carrying capacity of 7,500 per hour in one direction would be secured, or a total of 15,000 passengers.

The estimate of cost here given is based on prices and conditions for construction of roads in large cities such as New York, Philadelphia, Boston and Chicago. For smaller cities considerable reduction might be made.

As this paper is now quite lengthy, we deem in advisable to bring it to a close, omitting several subjects upon which we had intended to treat; and trusting we may be able to furnish a supplement in the near future. We give in conclusion a list of the cable roads now in operation and under construction.

LIST OF CABLE ROADS IN OPERATION AND UNDER CONSTRUCTION IN THE VARIOUS CITIES IN THE UNITED STATES.

Chicago.

Chicago City Railway Company: Cottage Grove Avenue, and State Street Lines, 20¼ miles, in operation since 1882; State Street and 63d. Street Line, 4 miles, under construction: Cottage Grove Avenue Extension, 4 miles, under construction.

North Chicago City Ry. Co.: 14 miles, under construction.

Cincinnati.

Mt. Adams & Eden Park Inclined R. R. Co.: Walnut Hills & Cincinnati Line, 8 miles, in operation since October 1, 1886.

Kansas City.

Kansas City Cable Ry. Co.: 4 miles, in operation since June, 1885.

Metropolitan Ry. Co.: 14 miles, under construction.

Corrigan Consolidated Ry. Co.: 16 miles, under construction.

New York City.

Third Avenue R. R. Co.: duplicate system; Tenth Avenue Line, 6 miles, in operation since August, 1885: 125th Street Line, 4½ miles, in operation since December 1, 1886.

Philadelphia.

Philadelphia Traction Co.: Market Street Line, 8 miles, in operation since the spring of 1885; Sansom Street Division, 4 miles, in operation since October, 1886; Columbia Avenue Division, 6 miles, in operation since the beginning of 1885.

St. Louis.

St. Louis Cable & Western Ry. Co.: 6 miles, in operation since April, 1886.

San Francisco.

California Street Cable R. R. Co.: 5½ miles, in operation since 1876.

Clay Street Hill R. R. Co.: 2 miles, in operation since August, 1873.

Geary Street Park & Ocean R. R. Co.: 5 miles, in operation since 1880.

Market Street R. R. Co.: Market street and branches, $16\frac{1}{2}$ miles, in operation since 1884.

Omnibus R. R. & Cable Co.

Sutter Street R. R. Co.: $3\frac{1}{2}$ miles, in operation since 1876.

Telegraph Hill Street Ry. Co.: 3,120 feet.

Several miles of road have recently been put in operation in Melbourne, Victoria, and about four years ago a road was built in New Zealand. In 1884, 2 or 3 miles were constructed in London, England.

DISCUSSION BY MR. AUGUSTINE W. WRIGHT.

I have listened with interest to the paper just read, describing Mr. Miller's Duplicate Cable System, and will attempt to follow the same in what I may say.

In "Wood's Treatise on Railways," there will be found the following: "In the year 1788, Mr. Reynolds completed, at the Ketley Iron-Works, an inclined plane, formed of a double iron railroad, by which a loaded boat in passing down a frame, constructed for the purpose, drew up the boats which were empty. Since that time many inclined planes have been made upon railroads for the purpose of drawing up the empty carriages by the gravitating power of the loaded carriages down the plane." * * * "In 1808, Mr. Cooke erected an engine upon Bertley Fell, in the County of Durham, to draw the loaded carriages up the Capetts Colliery, across the Durham and Newcastle turnpike road, in a steep ascent; and since that time they have been much used upon the railroads in the neighborhood of Newcastle."

The members present are doubtless all aware that when the Liverpool and Manchester Railway was about completed the question of motive power had to be considered. It was the original intention to operate that road by horse-power, but the cost of construction proved so great that it became evident that all the toll earned by horse transportation would not suffice for maintenance and interest on the investment. The Board of Directors thereupon decided to refer the question, "What under all circumstances is the best description of moving power to be employed upon Liverpool & Manchester Railway" to a committee consisting of Rastrick, Walker and (Robert) Stephenson, three of the most eminent engineers in England. Rastrick and Walker reported in favor of stationary engines, Stephenson in favor of locomotives. I have that report in my library, and it is very interesting at this day. The plan proposed was to have a train moving toward the power station draw a tail rope. The next train in the opposite direction would be drawn by the tail rope of the first train and draw behind it a rope to be used by the next train in the opposite direction, etc.

The cable system of to-day originated with the construction of the Clay Street Hill Cable Railway in 1873, by A. S. Hallidie and a few friends, in San Francisco. The grades of Clay street were so steep that property was not worth much, but the chances of success in the proposed cable road were considered so slight that property owners preferred to donate money, not deeming the stock of any value. The road was an immediate success, and the system was introduced upon other roads in San

Francisco. The steep grades, 17 feet in 100, of San Francisco were very favorable for cable operation, as compared with horse-power.

I agree most heartily with all Mr. Miller says of our fellow member Mr. Charles B. Holmes, of Chicago. It required no ordinary amount of pluck and determination for Mr. Holmes to peril his business reputation and advise his company to risk millions in the construction of a cable road in Chicago, when the variations of temperature, the climatic and traffic conditions were so great. I, for one, must admit that the venture did not meet with my approval. I did not believe it possible to use a cable twenty-five thousand feet long and in addition to moving all the cars with their loads propel another cable passing around five curves of about 50 feet radius and angles of 90 degrees. It is estimated that twenty-eight horse-power is required for each curve, but this rope does the business. As to the amount of *débris* that drops into the conduit through the slot opening in the street, this will vary not only with every city, but with each block of any street. If the adjoining streets are unpaved each vehicle will carry a greater or less amount of mud onto the paved street, where it drops off. I am informed that the average depth of mud dropping into the Chicago City Railway conduit does not exceed one and a half or two and a half inches deposit in winter months.

Cutting the Carrying Sheaves.— Ordinarily there are provided 165 carrying sheaves per mile of single track cable railway. The tendency was to make these carrying sheaves of the largest possible diameter, thus lessening the amount of power requisite to propel them. With the same size journal, it is evident that the amount of power required to turn the sheave will vary inversely as its radius. For instance, suppose that your journal is one inch in diameter. If the carrying sheave be 12 inches in diameter, and it required two pounds pull to turn it, should you substitute a carrying sheave of 24 inches diameter, one pound would suffice; but this leverage works both ways. Suppose you get one pound of ice or frozen mud on the rim of your carrying sheave. If one pound pull suffices, ordinarily applied to the circumference, to revolve the sheave, it is obvious that it will not revolve against the level of one pound of ice, and the cable would in a short time cut into and ruin the sheave. The carrying sheaves upon the Chicago City Railway were first made 16 inches in diameter, but the ice, etc., stopped their turning, and sheaves of 12 inches diameter have been substituted. The resonant ringing sound of which Mr. Miller speaks is attributed frequently to the method of carrying or supporting the sheave. If it is supported by wire lugs on the wire yoke the vibration is thought to be increased. To lessen this noise Messrs. Knight & Bontecou, engineers of the Grand Avenue Cable road in Kansas City, support the carrying sheaves on brick piers.

Regarding the construction, I should differ from Mr. Miller. To my mind, each cable road should *not* be built and planned entirely to withstand the street traffic. Where great variation in temperature exists, any structure strong enough to withstand the contraction and expansion of the paving or material composing the street surface will have abundant strength to carry any ordinary street traffic. The various roads have cost from $30,000 to $105,000 per mile of single track for street work.

Regarding the Duplicate Cable System, I would say that it is, in my opinion, simply increasing the first cost as a matter of insurance against detention, and I question whether it is worth the cost. This system is in use upon the Tenth avenue road of New York City and was put in upon the Kansas City Cable road, but afterward abandoned. The reasons given were as follows:

"1st. It took more time to change from one cable to the other than was required to repair a damaged cable.

"2d. The idle cable got cut and chafed by the running cable to such an extent as to render it useless when most required.

"3d. The idle cable by lying in the tunnel got covered with grit and dirt, which is very injurious to it. This objection could be overcome by moving the idle cable slowly with special engines erected for that purpose.

"4th. It involved increased expenditure of capital and labor for which there was no adequate return."

Carrying Sheaves.—Regarding this question, Mr. Henry Root, engineer of the Market street road in San Francisco, informed me that ordinary carrying sheaves had been running since 1878 in that city. The carrying sheave should be accurately balanced and trued up on emery wheels.

REPLY TO MR. WRIGHT—BY MR. MILLER.

Engineer Wright very honestly admits that the construction of the cable roads in Chicago did not meet with his approval, which is putting it very mild, to say the least.

Mr. Wright remarks "that it is estimated that 28 horse-power is required for each curve," presumably referring to the curves on the Chicago road. We take it for granted that he means the power required to move the cable, cars and passengers. For the four curves on the State street road, with nine miles of single track, it required about 115 horse-power to move cables, carrying and guiding pulleys, independent of driving machinery or cars.

Mr. Wright says, "ordinarily there are provided 165 carrying sheaves per mile of single track," and we presume that he has reference to wheels as spaced in Chicago, namely, at intervals of 32 feet. In New York we place them at intervals of 35 feet.

We judge that the information given by Mr. Wright in regard to hanging the pulleys is second hand, and that he does not speak from personal knowedge on this subject. In our experience we have found that a wheel attached to the truss of the road-bed, or resting on supports independent of the iron structure, or connected to the iron structure of the track with a block of wood inserted to break the metallic connection between the cable, track-rails and slot-rails, really has no effect on the resonance of the carrying pulleys. The ringing sound will be more or less controlled by circumstances; for instance, by the cable being filled with tar or running empty, new or worn cable, and also design of carrying pulley. A new rope with no tar will make considerable noise, whereas a worn cable well filled with tar will make comparatively none. The only way that the noise can be prevented is, as we stated, by filling the carrying pulley with some non-metallic substance.

However, the ringing is not sufficient to make any material difference in a street with much traffic.

As regards Mr. Wright's knowledge of the duplicate system, we find from his own remarks that this is extremely limited, and the four objections which he has taken from the *Street Railway Journal* are mere assertions made by a party in Kansas City, and these were fully answered about a year ago.

It must be remembered that the inventor of the duplicate cable system was never in Kansas City until the cable road there had been in operation some six months, and we think Mr. Wright somewhat unjust in quoting but one side of the controversy. If duplicate cables are a failure, then the whole cable system is a failure, for the simple reason that with single rope roads two cables are often operated in the same conduit, and under the same conditions as the duplicate cables are operated in the duplicate system, and we are pleased to inform Mr. Wright that the duplicate cables have been in successful operation on a section of the Chicago roads for four years.

The saving in the pay-roll with the duplicate system will more than pay the interest on the investment for the second rope, to say nothing of the great advantage of keeping the road in constant operation without use of horses.

Our paper was not intended to describe the duplicate system particularly, but we consider the notice justified by the unquestioned success of the Tenth Avenue Cable road.

Owing to the first cost, it is only practicable to adopt the cable system on lines carrying from two thousand to three thousand passengers per mile per day. The small additional cost for the second cable is but a "drop in the bucket" where so large an outlay is to be made, and when the objections to the single rope are considered, chief among which is the frequent stoppage and consequent detention of traffic, we fail to see the economy of doing without the second rope. Were cheapness the principal desideratum we would not construct a cable road.

It is not the investment alone, but the percentage to be realized on the investment, that is the question to be considered.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

ASSOCIATION OF ENGINEERING SOCIETIES.

MINUTES OF A MEETING OF THE BOARD OF MANAGERS—PROPOSED CONFEDERATION OF ENGINEERING SOCIETIES.

CHICAGO, Ill., April 15, 1887.

Meeting called to order by the Chairman, Benezette Williams, at his office, at ten o'clock A. M.

There were present Benezette Williams and L. E. Cooley, of the Western Society of Engineers, Chicago; W. S. Chaplin, of the Boston Society of Civil Engineers; C. J. A. Morris, of the Civil Engineers' Society of St. Paul; and J. B. Johnson, of the Engineers' Club of St. Louis.

Secretary Prout being absent, Mr. Johnson was elected Secretary *pro tem.* The Chairman stated the objects of the meeting to be to make a new arrangement for the printing of the JOURNAL, the election of officers of the Board, and the furthering of the original objects of the Association in the matter of a more inclusive and, perhaps, a closer union of the several engineering societies of the country.

After a full discussion of these subjects, it was ordered that the proposition submitted by Secretary Prout for the printing of the JOURNAL of the Association be accepted, provided that the number of surplus copies of each issue, over and above all takers, shall be at least fifty per cent. of the number taken in the Association, and that the remainder of these, on the termination of this contract, shall become the property of the Board of Managers; and provided that the publication shall appear as heretofore, as published by this Board; and provided that no article shall be allowed to appear in any periodical before the circulation of the copies of the JOURNAL which contain said article.

The application of the Engineers' Club of Kansas City to become a member of the Association was granted, thus making seven societies now in the Association.

Chairman Williams and Secretary Prout were unanimously re-elected to their respective offices. It was ordered that the Index Department remain under the general control of Mr. Johnson, as heretofore.

Messrs. Williams, Cooley, and Chaplin were appointed a committee to draft an address to the Societies now in the Association, on the subject of forming an organic confederation of engineering societies, and to report on the following day.

[*Adjourned.*] J. B. JOHNSON, Secretary *pro tem.*

CHICAGO, Ill., April 16, 1887.

Meeting called to order by the Chairman.

The Committee appointed to prepare an address to the Societies in the Association reported the following:

ADDRESS TO THE SOCIETIES NOW IN THE ASSOCIATION.

The Association of Engineering Societies was organized some six years ago, its primary purpose being the joint publication of the transactions of the various engineering societies of the country. The movement was looked upon with fore-

bodings by many, while others hoped that the habit of co-operation thus inaugurated would ultimately lead to a broader and closer union, national in its scope. The Association originally comprised the societies and clubs located at Boston, Cleveland, Chicago and St. Louis, with an aggregate membership of about four hundred.* The success attending the Association, and the enviable status of its publication, give abundant promise of permanence and of future growth.

The Board of Managers has always been disposed to encourage fuller co-operation, believing that there was a growing desire among engineers for a comprehensive organization which should represent them as a whole and as a profession. The efforts recently made in this direction do not seem to be fruitful in results, and we venture to ask that the societies in this Association, and all others interested, consider the advisability of taking steps which may lead to a national organization. If this shall appear desirable it would seem best to appoint delegates who may meet and discuss the many questions which must be settled before such an organization can be perfected.

In the absence of any authority which can act as intermediary, the Board offers its services in obtaining the sense of the several societies of the country and in any other way in which it may aid in this very desirable action. If the Societies of the Association favor such a movement, the Board respectfully suggests that it be empowered to issue a call and arrange for a convention.

In order to arrive at a conclusion in a practicable manner, the following specific proposition is submitted for the consideration of the Societies in the Association.

Proposed Action of Societies.

ARTICLE 1. The (here insert name of Society or Club) authorizes the Board of Managers of the Association of Engineering Societies, on the favorable action of two-thirds of the Societies in the Association, to call a convention of delegates from the several Societies of the Association, and such other societies as the Board may invite, said convention to consider the question of an organization of the several societies of the country in a confederation or such other union as may be found desirable. The Board is also empowered to lay before this convention such other matters as it may consider of general moment.

ART. 2. The Board of Managers may determine the time and place for such a convention. The representation of each participating Society shall be three votes and one additional for each fifty or fraction thereof in excess of one hundred members.

ART. 3. The conclusions of this convention shall not be binding upon any participating Society until ratified by said Society; and when two-thirds of the participating Societies have ratified the action of said convention, the proposed organization may go into effect.

The report was adopted and the Chairman was directed to send a copy of it to each of the Societies belonging to the Association.

In matters pertaining to the proposed convention of Engineering Societies, the Chairman was authorized to act for the Board.

The Chairman was authorized to address a letter to the Pittsburgh, Denver, Pacific Coast and Southern Engineering Societies, inviting them to become members of this Association.

It was ordered that the official documents of the Council of Engineering Societies upon National Public Works be published in the JOURNAL.

The Chairman and Secretary were authorized to levy an assessment on the Association to meet the obligations incurred by the contract for printing, and other necessary expenses, including the expenses of this meeting.

[*Adjourned sine die.*] J. B. JOHNSON, Secretary *pro tem.*

* Three other societies have since joined, and the total membership has nearly doubled.

BOSTON SOCIETY OF CIVIL ENGINEERS.

APRIL 20, 1887:—A regular meeting of the Boston Society of Civil Engineer, was held at Room 27, Boston & Albany Railroad Station, Boston, and called to order at 7:45 P. M., President L. Fred Rice in the chair, fifty-seven Members, seven visitors present.

The record of the last meeting and the annual dinner was read and approved.

Messrs. Simpson C. Heald and John C. Olmstead were elected Members of this Society.

Mr. Lemuel Pope was proposed for membership, recommended by F. P. Stearns, E. W. Howe. Mr. William A. Favor was proposed for membership, recommended by G. E. Evans, A. W. Hunking.

The Secretary presented the following list of Special Committees, appointed by the Government and authorized by a vote of the Society, passed at the last meeting:

Weights and Measures.—C. H. Swan, C. W. Kettell, C. W. Folsom.

Preservation of Timber.—President L. Fred Rice, E. W. Bowditch, J. B. Francis, W. Watson, E. K. Turner, H. Manley, H. Bissell.

National Public Works.—D. Fitz Gerald, W. E. McClintock, S. Smith.

Excursions.—D. Brackett, A. E. Burton, D. Fitz Gerald, W. S. Barbour, M. M. Tidd.

Library.—H. D. Woods, H. L. Eaton, C. S. Parsons, C. H. Swan, G. F. Swain.

The matter of the transfer of two hundred dollars from the permanent fund, to be devoted to the current expenses for the coming year, action on which was postponed for one month at the last meeting, was considered. Mr. E. W. Howe moved that the subject be laid on the table. Rejected. Mr. D. Fitz Gerald, that an assessment be made on Resident Members, at the option of the Government, to cover any deficit that may occur during the coming year. Rejected.

The previous question was then considered and was carried. The motion as adopted was: That the sum of two hundred dollars be transferred from the permanent fund and devoted to the current expenses of the Society.

Prof. G. F. Swain addressed the Society on "Details in Iron Bridge Work." The subject was illustrated by numerous diagrams, calculations and blue prints of numerous existing bridges.

Mr. Henry Manley explained the construction of the "Hewins Truss" of the Bussey Bridge and exhibited the broken hangers, two hangers taken from the opposite end of the bridge, and two hangers made by order of the Railroad Commissioners, one symmetrical, the other eccentric.

Professor Swain read a letter from Mr. E. S. Philbrick to the Railroad Commissioners giving the results of the test of one hanger taken from the "Hewins Truss," also one symmetric and one eccentric hanger similar to those taken from this truss.

The results of the test were as follows:

	Section. Sq in.	Elastic limit per sq. in.	Breaking strain per sq. in.
Old eccentric........................	4.03	25,000	35,770
New eccentric	3.80	7,900	34,740
New symmetric........................	3.58	8,380	33,240

Mr. Fred. Brooks exhibited a large collection of photographs, showing the construction of the bridge and the effect of the disaster.

[*Adjourned.*] H. L. EATON, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

MARCH 2, 1887 :—The Club met at 8:15 P. M. at Washington University, President Potter in the chair. 24 Members and 3 visitors present. The minutes of the last meeting were read and approved. The doings of the Executive Committee meeting of the same date were reported to the Club, recommending Alex. E. Abend, Chas. F. Muller, Max G. Schinke and Lewis Stockett for election to membership. They were balloted for and elected. The application of G. W. Dudley for membership, indorsed by J. B. Johnson and H. B. Gale, was announced and referred to the Executive Committee.

Robert Moore then read a paper on the "Present Aspects of the Problem of Inter-Oceanic Ship Transfer." A history of the various schemes which had been made public was given, as well as the results reached and the difficulties yet to be met. At present the question had narrowed down to three prominent routes, each of which has its supporters. The De Lesseps Panama Canal was discussed at length, the present condition of the work noted, its cost thus far, and the amount necessary to finish it shown. This, as well as the grave engineering difficulties to be solved, and on which the success of the work hinged, led the speaker to believe its completion impossible and its early collapse probable. The second scheme, known as the Tehuantepec route, was for topographical reasons not available for a canal, but has been chosen by Capt. Jas. B. Eads for his ship railway. This plan was also discussed at length, and its advantages and disadvantages considered. The great first cost, the cost of operating, and the serious and as yet unsolved engineering difficulties to be met, seemed to throw the preponderance of evidence against the enterprise. The third scheme was that known as the Lake Nicaragua Canal, which so far has not been as prominently mentioned as the others. While its first cost is undoubtedly great, it is not so large as either of the others, and its operating expenses would be much less. The work was of great magnitude, but yet of a character which had already in many instances been successfully handled, and in the whole route nothing new or untried would be met. On the whole, the speaker believed the Nicaragua scheme the one which best deserved the recognition and support of the American people. The paper was discussed by Messrs. Potter, Seddon, McMath, H. C. Moore and Ockerson.

[*Adjourned.*] WM. H. BRYAN, Secretary.

MARCH 16, 1887 :—Club met at 8.10 P. M., President Potter in the chair, 26 Members and 2 visitors present. The minutes of the last meeting were read and approved. The doings of the meeting of the Executive Committee, on same date, were reported, recommending Geo. W. Dudley for membership. He was balloted for and elected.

The President made the formal announcement of the death of Capt. Jas. B. Eads, suggesting appropriate action by the Club.

On motion, the President was directed to appoint a committee of three to draw up suitable resolutions. Messrs. McMath, Moore and Holman were appointed such committee. On vote, it was decided that the Club attend the funeral in a body.

The President announced the receipt from the Mississippi River Commission of a map of the alluvial basin of the Mississippi River from the St. Francis basin south.

Mr. Carl Gayler then read a paper on "Anchorage of Suspension Bridges," describing the common practice, and making some criticisms ; also suggesting certain improvements, as adopted in the city's practice. The paper was discussed by Messrs. Johnson, Frith, Holden, Seddon, Macklind, Moore.

[*Adjourned.*] WM. H. BRYAN, Secretary.

APRIL 6, 1887 :—The Club met at 8:15 P. M. at Washington University, Vice-President Holman in the chair, 28 Members and 4 visitors present. The minutes of the meeting of March 16 were read and approved. The Executive Committee reported the doings of its meeting of same date. The Committee on Resolutions on the death of Capt. Jas. B. Eads asked for further time to prepare a report, which extension was granted.

S. Bent Russell then read a paper on "Draining and Filling Water Mains," describing the system of operations in use in this city, where shut-offs average one per day. The difficulties met with and the precautions to be taken were duly treated upon. In the discussion Mr. Holman gave some interesting points in his experience bearing on this question.

Prof. C. M. Woodward opened the discussion on the failure of the Bussey bridge on the Providence & Boston Railroad, describing fully the nature of the accident and illustrating the details by sketches on the blackboard. His explanation of the cause of the accident was full and clear. The matter was also discussed by Messrs. Seddon, Frith, Johnson and Moore. The recent full publications and illustrations in the *Engineering News* were favorably commented upon.

Professor Johnson announced that there would be a meeting of the Board of Managers of the Association of Engineering Societies at Chicago at an early date, and asked that suggestions as to the management of the Association be made. Several topics were brought forward and discussed.

[*Adjourned.*] W. H. BRYAN, Secretary.

APRIL 20, 1887 :—Club met at 8:15 P. M. at Washington University, President Potter in the chair, sixteen Members and two visitors present. The minutes of the last meeting were read and approved.

Mr. McMath, Chairman of the Committee on Resolutions on the death of Capt. J. B. Eads, submitted a report, which, on vote, was received. It was directed that the report be spread upon the records of the Club, and a copy sent to the family of the deceased. It reads :

By the death of James B. Eads, which occurred on the 8th of March, 1887, the Engineers' Club of St. Louis loses a Member, of whose world-wide fame it may well be proud. To but few engineers in the history of the profession has it been given to surmount greater obstacles or accomplish works as great. The builder of the St. Louis Bridge, in many ways a work without precedent, and of the South Pass Jetties, whereby the commerce of the Mississippi Valley was, for the first time, given a free outlet to the sea, well deserves a high rank among the benefactors of the race, and sheds a new lustre upon the profession whose calling it is to subdue the forces of nature to the uses of mankind.

And these works were his in a more than usual sense, in that the skill which enabled him to do them was not learned in any school, but was the outgrowth of his own genius and his own readings of Nature's laws, and for the further reason that the money necessary for their accomplishment was contributed mainly because of the faith which his own deep-rooted confidence and enthusiasm never failed to inspire in others.

In parting with him now, after a long and well-spent life, our Club loses its most distinguished Member, our profession one of its brightest lights, and the world one of the most potent factors in its material advancement.

Professor Johnson made a verbal report of the recent meeting of the Board of Managers of the Association of Engineering Societies at Chicago. The new arrangements made for the publication of the Journal were reported, and its regular appearance in future promised.

Mr. C. W. Clark then read a paper on "Experiments with Submerged Adjutages," describing some experiments made at the University of Illinois. He

deduced the results, giving the co-efficient of discharge for each form of adjutage experimented with. The paper was discussed by Professor Johnson, J. A. Seddon, Russell, Professor Gale and R. E. McMath.

A paper by Col. E. D. Meier was announced for the next meeting.

[*Adjourned.*] WM. H. BRYAN, Secretary.

WESTERN SOCIETY OF ENGINEERS.

MARCH 1, 1887:—The 234th meeting was held at 7:30 P. M.

The minutes of the preceding meeting were read and approved.

Application for membership was received from :

Stephen Francis Balcom, Assistant Roadmaster, Illinois Central R. R., Champaign, Ill.

The following gentlemen were elected Members :

Charles C. Breed, Resident Engineer, Maysville & Big Sandy R. R , Louisville, Jefferson Co., Ky.

Simeon C. Colton, Engineer for FitzSimons & Connell, 217 E. Ohio street, Chicago.

Daniel W. Mead, City Engineer, Rockford, Ill.

Hubert A. Stevens, Assistant Engineer North Chicago Cable R. R., 145 Loomis street, Chicago.

William J. Yoder, Resident Engineer, Chicago, Madison & Northern R. R., Wayne, Du Page Co., Ill.

The President announced the following Topical Committees :

Surveys and Topography—S. S. Greeley, B. Feind, Peter Heer.

Materials—I. O. Baker, Chas. E. Billin, E. Hemberle.

Construction—C. L. Strobel, H. W. Parkhurst, Allan D. Conover.

Bridges—J. A. L. Waddell, W. L. Baker, A. Gottlieb.

Transportation—Geo. S. Morison, O. Chanute, A. W. Wright.

River and Harbor Improvements—T. T. Johnston, O. M. Poe, G. A. M. Liljencrantz.

Water Supply and Sewerage—J. D. Cook, J. A. Cole, O. H. Cheney.

Fuel, Heat for Industrial Purposes—J. Zellweger, Morris Sellers, D. C. Cregier.

Lighting, Heating and Ventilation—W. L. B. Jenney, D. Adler, Jas. R. Willett.

Mining—M. A. Meyendorff, W. A. Hammett, Geo. T. Wickes.

Tools and Machinery—A. Sinclair, E. Foote, Jr., Chas. S. Pease.

Jurisprudence of Surveys—J. M. Bourne, C. W. Irish.

Weights and Measures—Chas. Latimer, S. S. Greeley.

City Engineering—S. A. Bullard, B. Schreiner, A. H. Bell.

National Public Works—L. E. Cooley, H. B. Herr, R. A. Brown.

The Secretary read a paper by Mr. D J. Miller, Traction Rope Railways.

Owing to the lateness of the hour, reading of paper by Mr. J. T. Dodge, Tunneling in Montana, was postponed to the next meeting.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

APRIL 5, 1887:—The 235th meeting was held on Tuesday, April 5, 1887, at 7:30 P. M., ex-President Wright in the chair.

The minutes of the preceding meeting were read and approved.

Applications for membership were received from :

Robert Gillham, Civil Engineer, Kansas City, Mo.

Frank Churchill Horn, Principal Assistant Engineer, Town of Lake, Cook County, Ill.

Mr. Stephen Francis Balcom, Assistant Engineer, Illinois Central Railroad, Champaign, Ill , was elected a Member.

The Secretary read a letter from Mr. Chanute, saying it was impossible for him to serve as a member of Committee on Transportation.

Two papers were read and discussed: Tunneling in Montana, by Mr. J. T. Dodge, and Wood Preserving, by Mr. J. P. Card.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

ENGINEERS' CLUB OF MINNESOTA.

MARCH 11, 1887:—Regular meeting, President G. W. Sublette in the chair. Present, J. H. Barr, W. R. Hoag, Wm. W. Redfield, M. J. Riggs and G. W. Sturtevant. Secretary Pardee being absent, G. W. Sturtevant was appointed Secretary *pro tem.*

Records of previous meeting were read and approved.

The Secretary read a letter from H. M. Waite, relative to continuance of membership in the Society and to his back dues: also a letter from Hon. C. K. Davis, relative to copies of U. S. Reports for the library of the Club.

Then followed a general discussion in regard to attendance at the Club meetings and suggestions as to how best to increase the same.

On motion it was unanimously voted to adopt the resolution passed at the last regular meeting to change Art. 1 of the By-Laws as per resolution of that date. Mr. Barr here presented a communication from Prof. Pike inviting the Club to hold its next meeting at the College of Mechanic Arts, State University, and have an opportunity to inspect the apparatus of the various departments of same, and on motion, it was voted to accept the invitation of Prof. Pike, and hold the next meeting of the Club at the University as per said invitation.

The following were elected to membership in the Club: C. O. Huntress, Franklin Cook and P. M. Dahl.

The literary exercise consisted of an interesting discussion of the New York Harbor Improvement, as proposed by the Board of United States Engineers, the question being discussed by nearly all the members present. On motion it was voted to continue the discussion of the New York Harbor Improvement at the next meeting.

President Sublette gave notice that he would read a paper on Railroad Bridge Lettings at the next meeting of the Club.

[*Adjourned.*] GEO. W. STURTEVANT, Secretary *pro tem.*

APRIL 9, 1887:—Regular meeting at State College of Mechanic Arts University grounds, East Minneapolis, pursuant to an invitation extended to the Members of the Club at a previous meeting by Prof. Wm. A. Pike of the University. Meeting called to order by Pres. Geo. W. Sublette at 8 P. M. Present, J. H. Barr, F. W. Cappelen, Wm. De Le Barre, F. C. Deterly, Wm. R. Hoag, G. Sidney Houston, J. M. Hazen, Wm. A. Pike, W. W. and C. L. Redfield, M. J. Riggs, George W. Sturtevant, R. H. Sanford, F. L. Straw, P. B. Winston and W. S. Pardee.

On motion, the regular order of business was suspended in order to examine the new college and the apparatus recently set up, for the purpose of testing the materials. The Club inspected the basement, which contains the machine and vise-shop, wood and pattern-shop, testing laboratory, forge-shop, foundry, engine and boiler-room; also on the first story the civil engineers', mechanical engineers' and physical recitation rooms, apparatus room, dark room and physical laboratory; lastly, on the second floor, general and engineers' drawing-room, blue-print room and engineers' apparatus room.

After the tour of inspection, illustrative tests were made on the Oleson 50,000-pound machine, of transverse strength of pine and tensile strength of iron. Following this were numerous tests with Tabor's steam indicator on the University

engine. The Club then adjourned to the physical recitation room. On motion of Mr. De Le Barre the Club extended a vote of thanks to Prof. Pike for the corteous manner in which they had been entertained, and expressed high appreciation of the good organization of the college and its efficient apparatus. On motion, the subject of New York Harbor and Coast Defense was referred to a committee of three, Messrs. Geo. W. Sturtevant, Wm. De Le Barre and Wm. A. Pike, with instructions to report at the next meeting as to the sense of the Club relative to the matter.

On motion, the subject of Wire Ropes was referred until the next meeting.

Messrs. James Rigby and O. W. Burnham were proposed for membership.

[*Adjourned.*]

APRIL 22, 1887.—Regular meeting Civil Engineers' Club of Minnesota, at City Hall, 7:30 P. M. President Geo. W. Sublette in the chair. Members present, Messrs. M. J. Riggs, Wm. W. Redfield, F. C. Deterly, G. S. Houston, W. S. Pardee.

The minutes of the previous meeting were read and approved. On report of Committee on Library, Mr. Wm. W. Redfield stated that after having communicated with Mr. H. G. Prout, Secretary Association Engineering Societies, he had found the Association Journal could be procured from the beginning of its publication at a reasonable cost, and on motion of Mr. Houston, with amendments thereto, an offer was accepted from Mr. Redfield donating to the club $7, to be used in procuring back numbers of the Association Journal, the balance of the amount to be furnished by the Club.

On motion of Mr. Riggs it was voted that an offer be accepted from G. Sidney Houston, presenting the Club with the periodical *Engineering* for the year 1887. On motion, Mr. Houston and Mr. Redfield were extended a vote of thanks for their kind propositions.

On motion of Mr. Houston, a committee be appointed to wait upon and notify the remaining delinquent members of their assessments and collect the same.

Committee appointed were Messrs. Houston and Pardee.

A motion was proposed to amend Article 10 of the By-Laws.

Discussion of Wire Ropes was again deferred, and no report being received from the Committee on New York Harbor and Coast Defense, after the proposal to membership of the names of J. E. Turner and G. Carry, the Club adjourned.

WALTER S. PARDEE, Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. VI. June, 1887. No. 6.

ERRATUM.—In the Proceedings of the Boston Society of Civil Engineers as published in the JOURNAL for May, the table showing the results of tests of hangers should have been printed as follows:

	Section. Sq. in.	Elastic limit per sq. in.	Breaking strain per sq. in.
New symmetric....................	4.03	25.000	35.770
Old eccentric....................	3.80	7.900	34,740
New eccentric....................	3.58	8.380	33,240

tain a complete understanding of the subject and fully appreciate the future possibilities in this direction.

The practical questions of leakage, dangers from explosions and the controlling of gas under high pressures have been solved by those working in this field, and I will give the facts as determined from practical working in Pittsburgh and Allegheny City. I quote from results given to the public by the Philadelphia Co., Pittsburgh.

"It being practically impossible to make a series of joints in the ordinary way that could be depended upon to remain gas tight; the attention of inventors and engineers was then directed to devising and perfecting suitable safety appliances, first to make the joints more secure, and second to confine within certain limits any escaping gas, and to conduct it through auxiliary pipes to places where it could escape safely. Such a system was perfected and applied to more than 100 miles of pipes in Pittsburgh and Allegheny City, with the most gratifying results; by its use the actual loss of gas by leakage is less than one per cent., and the danger of explosions from this source is, therefore, practically overcome. They have also devised the means of detecting and readily locating any leaks that may occur, without having to tear up the street to locate the same.

"Automatic pressure regulators have also been devised and patented, by which the pressure can be so accurately adjusted that the pressure of the gas as it enters the regulator through the inlet pipe may have a wide range of variation, but when it passes out of and beyond the regulator it will maintain a constant pressure of any degree required. Automatic shut-off valves and temperature regulators have also been devised." Mr. Bannister, in his book from which I have quoted above, closes as follows: "That the problems presented to the inventor and his coadjutors by the

engine. The Club then adjourned to the physical recitation room. On motion of Mr. De Le Barre the Club extended a vote of thanks to Prof. Pike for the courteous manner in which they had been entertained, and expressed high appreciation of the good organization of the college and its efficient apparatus. On motion, the subject of New York Harbor and Coast Defense was referred to a committee of three, Messrs. Geo. W. Sturtevant, Wm. De Le Barre and Wm. A. Pike, with instructions to report at the next meeting as to the sense of the Club relative to the matter.

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THE TRANSMISSION OF NATURAL GAS LONG DISTANCES.

BY GEO. H. CHRISTIAN.

[Read by request, February 8, 1887.]

The question of the pipage of natural gas long distances by its own pressure is one of great importance at the present time. We can hardly read a scientific paper that this subject is not spoken of, and various opinions expressed, but it is only by constant discussion that we can obtain a complete understanding of the subject and fully appreciate the future possibilities in this direction.

The practical questions of leakage, dangers from explosions and the controlling of gas under high pressures have been solved by those working in this field, and I will give the facts as determined from practical working in Pittsburgh and Allegheny City. I quote from results given to the public by the Philadelphia Co., Pittsburgh.

"It being practically impossible to make a series of joints in the ordinary way that could be depended upon to remain gas tight; the attention of inventors and engineers was then directed to devising and perfecting suitable safety appliances, first to make the joints more secure, and second to confine within certain limits any escaping gas, and to conduct it through auxiliary pipes to places where it could escape safely. Such a system was perfected and applied to more than 100 miles of pipes in Pittsburgh and Allegheny City, with the most gratifying results; by its use the actual loss of gas by leakage is less than one per cent., and the danger of explosions from this source is, therefore, practically overcome. They have also devised the means of detecting and readily locating any leaks that may occur, without having to tear up the street to locate the same.

"Automatic pressure regulators have also been devised and patented, by which the pressure can be so accurately adjusted that the pressure of the gas as it enters the regulator through the inlet pipe may have a wide range of variation, but when it passes out of and beyond the regulator it will maintain a constant pressure of any degree required. Automatic shut-off valves and temperature regulators have also been devised." Mr. Bannister, in his book from which I have quoted above, closes as follows: "That the problems presented to the inventor and his coadjutors by the

occurrence of natural gas have been completely solved must now be apparent to all. The pipe systems and appliances for insuring safety and preventing waste in its conveyance and distribution, and the devices for its perfect adaptation to every use as fuel, have been brought to such a high state of perfection that there is really nothing further to be desired."

It is left for us to but demonstrate the possibility of conveying this fluid in large quantities great distances by its own pressure, to induce capital to flow into this channel of trade. It is claimed by many that there is a limit in distance soon reached beyond which the cost of plant in proportion to quantity of gas delivered will render it impossible to give more than a few cities in this country the benefit of this fuel; and we see daily instances of the effect of this view in manufacturers moving their factories to places where natural gas is found in abundance. In an issue of *Van Nostrand's Magazine* can be found a scientific discussion on the flow of compressed air, and formula deduced almost identical to the water formula "for flow of water through pipes." This article is from the pen of Prof. Robinson of the State University.

You will find his formula, derived from the principle of adiabatic expansion of gases, to exactly coincide with results obtained by a formula which I shall use, and which is derived from considering the work done by the expansion and friction of the gas; these facts, I believe, clearly prove the correctness of both. We will not go into the mathematics of this subject, but consider the forces acting when gas is flowing, and determine analytically the results.

Let us take a pipe of large diameter and great length, connected with a number of gas wells, allow this pipe to fill and the terminal pressure to reach that at the wells. Now let us open a valve at delivery end, and ascertain the quantity discharged; which quantity will depend upon the following variables: The pressure of the wells and the length and diameter of your pipe line; the forces at work are expansion and friction, and it is the latter force we must determine.

From our knowledge of the flow of water through pipes, we have total head H in a line of pipe, equals $h + h'$ where h is velocity head and h' friction head. Now these are the only losses on the supposition that the gas maintains constant temperature. We can then, having given the initial pressure, distance and size of pipe, determine the friction, loss and quantity discharged. In applying the formula for discharge you will find that the friction loss in uniform diameter pipe line increases in a rapid ratio as you approach the end of your line, and that to pipe gas with least outlay of plant your pipe must be of variable diameter, and it remains to ascertain the degree of this increase; to do so let us look at the equation of friction, which is written thus:

$$F = CH \frac{L}{D} S = F.$$

$C =$ constant.
$F =$ total friction.
$H =$ velocity head in pounds per square inch.
$L =$ length in feet.
$D =$ diameter in feet.
$S =$ co-efficient of friction.

From this formula we see that the friction increases as the square of the velocity, inversely as the diameter of pipe and directly as the length; also directly as the quotient of the pressure in pounds per square inch above vacuo divided by atmospheric pressure. Your pressure decreases as you advance from the wells, and your velocity increases; the density of your gas, however, decreases, so that your friction loss on this account will not increase as the square of the velocity, but more nearly as to the velocity. By increasing the diameter of your pipe to meet this increased velocity, and thereby maintaining a more constant velocity, you can keep your friction loss within small bounds.

To lay out a pipe line so that its friction losses shall remain within the pressure available, we have but to keep in mind this fact, that in steady motion the same weight of fluid must pass each cross-section in a unit of time, whether your pipe is of uniform or variable diameter. Let us, then, take an example: Suppose we are required to determine the cheapest line of pipe possible to transport 225,000,000 cubic feet daily, and deliver same at terminus of line 300 miles distant from wells, having an available pressure at wells of 300 pounds per square inch. We will assume the initial diameter of pipe line to be 2 feet; a discharge of 225,000,000 cubic feet per day would be 2,600 cubic feet per second. The area of pipe 2 feet diameter is 3.1416 square feet. 2,600 divided by this area, 3.1416, equals 821. This divided by $\frac{314.7}{14.7}$ equals 39 feet per second as velocity in first mile, and from the formula for friction for gas specific gravity 0.6, the loss in friction for the first mile will be 5.2 pounds. Now, if we should continue our pipe 2 feet in diameter for 10 miles, we will have a velocity in the tenth mile of 47 feet per second, and a friction loss of 6.4 pounds, making a total loss for friction in the first 10 miles of pipe 58 pounds, and will leave you a pressure at the eleventh mile of 242 pounds; here let us increase to 2½ feet diameter and continue this diameter for 30 miles; your velocity and friction loss in first mile will be 30½ feet per second velocity, and 2 pounds per mile friction loss, and in the last mile of 2½ feet pipe velocity 41 feet per second, friction loss 2.76 pounds per mile, making a total loss of 70 pounds in the 30 miles, and leaving a pressure of 172 pounds at the forty-first mile point; here we will increase to 3 feet diameter and continue same 20 miles. Your velocity in first mile will be 29.3 feet per second, and friction loss of 1.15 pounds per mile, and in last mile of 3 feet pipe, velocity 34 feet per second, friction loss, 1.38 pounds per mile, making a total loss of 25 pounds in the 20 miles, and leaving a pressure of 147 pounds at the sixty-first mile point; here we will increase to 3½ feet diameter, and continue same for 15 miles, the velocity in first mile will be 25 feet per second, and friction loss 0.6 pounds per mile, and in last mile velocity 27 feet per second, friction loss 0.68 pounds per mile; total loss in 15 miles 10 pounds, leaving a pressure of 137 pounds at the seventy sixth mile point; here we will increase to 4 feet diameter and maintain same to terminus of your line, or for 225 miles, and your total loss in that distance will be 136.8 pounds, leaving 0.2 pounds pressure to maintain the flow of gas there of 207 feet per second.

Our pipe line beginning 2 feet in diameter and ending 4 feet will

transport 225,000,000 cubic feet every 24 hours with an initial pressure of 300 pounds per square inch. This line, I believe, you will find to be the cheapest that could be built to do that work, but for other considerations it would be better to lay a double line of pipe for the more perfect protection of your consumers in case of accident to one line. Having calculated for a pipe of initial diameter of 2 feet, we can readily ascertain what initial diameter would be required using two pipes to convey the same amount of gas, and you would find that two lines beginning 18 inches diameter and ending 3 feet will deliver nearly the same amount, as the 2-4 foot single line will do. I wish to show you a peculiarity of these friction losses. Let us take a pipe 4 feet diameter and continue this diameter the 300 miles, and assume a discharge same as before, 225,000,000 cubic feet daily, what initial pressure would be required?

Beginning at the terminus and working backward, we will find the losses thus:

1st to 6th mile	6 miles	14½ lbs.
6th " 18th "	12 "	17 "
18th " 36th "	18 "	17 "
36th " 60th "	24 "	17 "
60th " 90th "	30 "	17 "
90th " 126th "	36 "	17 "
126th " 168th "	42 "	17 "
168th " 216th "	48 "	17 "
216th " 270th "	54 "	17 "
270th " 300th "	30 "	8½ "
	300 miles.	Friction loss 159 lbs.

The friction loss remaining the same for every additional increment of 6 miles, thus you would need but 160 pounds of well pressure to transport 225,000,000 cubic feet daily 300 miles through a pipe 4 feet diameter throughout. Again you can readily obtain total friction loss in any pipe line of constant diameter, length and pressure given. Assume a discharge, calculate the friction loss in first mile, multiply this friction loss by the number of times in density the gas in first mile is above atmosphere, add to this the friction loss in last mile and divide this sum by $(\frac{PO}{P} \times 1)$. PO equals initial pressure above vacuo. P equals 14.7 atmosphere pressure. Thus, for last example: Terminal velocity 207 feet per second, inital pressure 159 pounds. $\frac{159 + 14.7}{14.7} = 11.6$. The friction loss in first mile will be 0.3 pound. This multiplied by 11.6 equals 3.48 pounds; friction loss in last mile 3.2 pounds; adding 3.48 + 3.2 equals 6.68 $\frac{6.68}{11.6 + 1} = 0.53$ pound as average friction loss per mile, and for 300 miles 0.53×300 equals 159 pounds as before. This renders quite simple what would otherwise be a tedious calculation. Let us now look into the cost of our pipe line.

The average pressure in the 10 miles of 2-foot pipe would be 275 pounds. But since there would be times when the whole pressure of 300 pounds would be on the whole length of 10 miles, it should be made sufficiently strong to safely withstand the same. The thickness of said pipe should be, if of wrought iron or steel plate, ⅜ inch thickness, costing $25,000 per mile complete. The 2¼-foot pipe would also have to stand 300 pounds

pressure, and would have to be $\frac{7}{16}$ inch thickness, and cost $37,000 per mile. Here an automatic governor should be placed in your pipe, so as not to allow a greater pressure beyond this point than 225 pounds per square inch, for if the pipe line was doing its full capacity, the pressure would be but 172 pounds, and less on the 3-foot pipe. With 225 pounds pressure, thickness of pipe would be $\frac{3}{8}$ inch and cost $37,000 per mile. Your $3\frac{1}{2}$ feet diameter would require to be $\frac{7}{16}$ inch thickness, and cost $45,000 per mile. Here, again, an automatic pressure regulator should be placed to prevent the pressure beyond exceeding 160 pounds maximum, and your 4 feet would average in thickness throughout its entire length $\frac{1}{4}$ inch, and cost $30,000 per mile. This would make your pipe line net complete ten million dollars: add to this the cost of right of way, gas property, drilling of wells and city pipe system, and your total cost of plant would be nearly $16,000,000.

In the above estimate, I have assumed the pipe to be of wrought iron boiler plate, double riveted, and to be laid above ground; and arrangments made for the contraction which must take place when the gas is turned on, either by using expansion joints or laying the pipe in a wavy line.

There is another material that could be used, which, I think, would be even cheaper than riveted work, and that is open-hearth or Bessemer cast steel pipe. This metal can be made in large amounts possessing a tensile strength of 60,000 pounds per square inch, and allowing a factor of safety of 10, you would have the same strength for each inch cross section as from a 3 inch cross section of cast iron, and the weight would thus be one-third lighter than cast iron, but heavier than boiler plate. These pipe ought to be made for $2\frac{1}{4}$ cents per pound, or even less for such large pipe. It is not my intention to go into the detail of cost, but simply to to show that a pipe line can be laid to carry a large quantity of gas a great distance, and at a cost within bounds. At first sight, the sum of $16,000,000 might seem to be so great as to preclude capitalists from investing in such a scheme, but when we estimate the receipts from sale of this gas, we will probably change our minds.

One thousand cubic feet of natural gas contain 1,000,000 heat units; one bushel, or eighty pounds of hard coal, 1,200,000 heat units. In burning gas for domestic purposes you realize 50 per cent. more of its heat than from burning coal, or your gas would be equal to 100 pounds. of hard coal. Hard coal in New York City or Philadelphia is worth $5 per ton, or 25 cents per 100 pounds. If we should sell this gas for $12\frac{1}{2}$ cents per 1,000 cubit feet, it would reduce the cost of fuel to the consumers 50 per cent. The daily receipts from sale of 200,000,000 would be $25,000, or $10,000,000 per year. Allowing fifteen per cent. on investment, you have remaining for yearly running expenses, improvements, repairs and sinking fund $7,750,000.

You may ask how is it that you figure such a large revenue, when in Pittsburgh their total yearly revenue is but $2,500,000? The facts are, in Pittsburgh soft coal is used and sells for $1.25 per ton as against $5 in New York.

If you should pipe from Findlay Field to Chicago, you could not realize over 10 cents per 1,000 cubic feet, but even here $8,000,000 per year revenues should pay handsomely.

Cleveland and Cincinnati are both nearer the gas territory, and the cost of plant very much less. These places must very soon avail themselves of this cheap fuel.

It remains, in my opinion, but to determine the permanency of the supply of this fuel to induce capital into this channel of business, and we can look in the near future for the building of vast systems of pipe lines to all manufacturing centres in this country.

There is another question I should like to have this society consider, and that is to determine the quantity of gas discharged from an orifice under heavy pressures.

Professor Robinson, of this State, and others went to Findlay last summer to make some measurements of the gas wells, and in his pamphlet he gives several examples of the pressures and discharges of same, also a most interesting account of his experiments with the Pitot tube for measuring dynamic and static pressures, and showing the very great accuracy of the Pitot tube; he settled this point by his experiments, that outside of the plane of the orifice there was no static pressure, while inside there was both static and dynamic; in other words, at the plane of the orifice the static pressure becomes dynamic and does work.

We will consider one of the examples given in his book, the Kurg well. The pressure at the end of a 4-inch pipe when the valve was full open was 15 pounds per square inch; from this he calculates by the adiabatic formula the velocity of flow to be 1,513 feet per second, and as the area of 4-inch pipe is 0.0873 square feet, the discharge per second would be 132 cubic feet, or 12,000,000 cubic feet per 24 hours. What is this velocity in this case?

If we calculate the velocities of fluids of 0.6 specific gravity and 1.2 specific gravity, under pressures of 15 pounds per square inch, assuming each fluid as incompressible, the velocities would be 1,778 feet and 1,244 feet; if we add these and divide by 2 we have an average velocity of 1,511 feet per second. This is the average velocity of flow; but is it as he makes it, the average velocity for a gas of 0.6 density? Is it not the velocity for a gas of average density between 0.6 and 1.2, which would make the discharge 18,000,000 instead of 12,000,000 cubic feet per day? That it is surely more than 12 million I think I can clearly prove.

If the gas was incompressible and of specific gravity 0.6, its velocity of flow would be, under 15 pounds pressure, 1,778 feet per second, and quantity discharged 13½ million cubic feet.

From the formula $V=\sqrt{2\,g\,h}$ we have the velocity varies directly as the square root of the height, the height varies inversely as the densities, and therefore the weight of fluid flowing per second would vary inversely as the square root of the height, thus a greater weight of fluid would flow per second from a pressure of one pound on water than from one pound pressure on air, or from one pound on gas of specific gravity 1.2, than from one pound on gas of specific gravity 0.6, and that this would be inversely as to the square roots of the heights, which in this case would be as $\sqrt{1} : \sqrt{2}$ or 18 million cubic feet per day. Again, take gas specific gravity 0.6 under one pound pressure, velocity would be 456 feet per second; assuming one square foot area of orifice and one cubic foot

of gas, specific gravity 0.6 = one pound in weight, the weight of flow would be 456 pounds per second, gas at specific gravity 1.2 under one pound pressure, velocity would be 318 feet per second, and weight 318× 2 = 636 pounds per second.

Calculated by the adiabatic formula your velocity would be 430 feet per second, and by Professor Robinson's method but 430 pounds, 26 pounds less than 456 pounds; which must be wrong. To me it would seem to be correct to calculate the velocity of flow due to pressure and density, multiply this velocity by the number of times the gas is in density greater than gas is at atmospheric density, then by area of opening, etc. Thus 15 pounds pressure its density would be 1.2 and velocity 1,244 feet per second, multiply 1,244 by $\frac{1.2}{0.6} = 2 \times 1{,}244$, we would have $2{,}488 \times .0873 \times 86{,}400$, we would have 18 million cubic feet discharge per day.

There is still another method of proof. Calculate the initial velocity by this formula where the length of pipe is quite short:

$$V_0 = \sqrt{\frac{g \times ct\ (P_0{}^2 - P_1{}^2)}{P_0{}^2 \left(S\frac{4\,l}{d} + log.\frac{P_0}{P_1}\right)}}$$

$g = 32.$
$c\,t = 47{,}000.$
d = diam. in feet.
l = length " pipe.
s = coef. friction, .006.
P_0 and P_1 = initial and terminal pressures per square foot above vacuo.

The terminal pressure in this case is 15 pounds, or 29.6 pounds above vacuo; the initial pressure say for a length of 10 feet can be figured by calculating the friction loss in that distance; the following formula will give you the weight of the fluid flowing per second:

$$w = \frac{n}{4}\sqrt{\frac{g\,d^4\,(P_0{}^2 - P_1{}^2)}{\left(S\frac{4\,l}{d} + log.\frac{P_0}{P_1}\right)ct}},$$

where $n = 3.1416$.

If you will work this by this formula you will find the weight of fluid flowing per second to be 9.6 pounds, which would be the weight of 210 cubic feet of gas, specific gravity 0.6, or a discharge of 18 million cubic feet per day.

MEMOIR OF CLARENCE WILLIAMS LUNT.

MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

BORN NOV. 9, 1850; DIED FEB. 22, 1884.

Mr. Lunt was born in Portland, Maine. His parents removed to Roxbury when he was ten years old. He was educated in the public schools, going through the Grammar and into the Roxbury High School. He was a good scholar, excelling in mathematics.

He was small in stature, and never very strong. He entered the office of T. & J. Doane in Charlestown as a student of engineering October 1,

1866, and remained till June 18, 1869. About this time he went West with Mr. Thomas Doane to Nebraska, and entered the service of the B. & M. R. R. R. in Nebraska, where he was engaged as resident upon the Plattsmouth division of that road. Later he was employed in Missouri, where his health failed him, and he suffered a slight shock of paralysis. After returning home and partially recovering his health, he became associated with Mr. H. H. Moses, in Roxbury. While in this office he married, December 19, 1877, Miss Sarah Margaret Smith, of Roxbury, who had been a school mate and youthful acquaintance. In 1879 he became associated in business with Mr. Arthur Hodges, and this continued to the time of his death.

In the summer of 1881, office work being dull, Mr. Lunt was engaged in railroad surveying in Pennsylvania, but in a few months was again driven home by ill health. In 1882 he seemed through the first half of the year in the best of health, but in the fall the first symptoms of paralysis of the throat and of consumption developed. Thinking a southern climate would benefit him, he undertook the next year some professional work in connection with silver mines, of Sonora, and gold mines of the Indian Territory, but finding himself running down rapidly, he again returned home in September, 1883, not again to leave it professionally.

In the last year of his life he became a member of the Masonic Fraternity, which was the source of considerable comfort to him.

He was of studious habits, reserved in manner, sensitive in disposition. These were qualities not usually appreciated in the professional life of the engineer, and not of the kind to enable him to push his way in the world.

He spent his evenings usually with his family when not professionally absent, was a lover of home, and excluded his business matters from it.

He leaves a widow and three children. The names of the children are Margaret Sargent, Dwight Smith and Olive Ann Meserve, aged now respectively 7, 6 and 4 years. He left a small property, which, with the wife's patrimony, places them in comfortable circumstances.

Mr. Lunt is buried at Forest Hills Cemetery, in the Smith lot.

Mr. Lunt was elected to membership in the Boston Society of Civil Engineers, Oct. 20, 1875. In 1882-83 he represented the Society as one of the committee of three on "The Metric System of Weights and Measures," and his name is signed to a very important report of this Committee made to the Society at its annual meeting, March 21, 1883.

The following tribute to his memory is from Rev. A. H. Plumb, the pastor of his father's family, who saw much of him during his sickness.

"Mr. Lunt was an uncommonly intelligent man. He did not confine his researches to his professional studies. He read much and on a wide range of topics. On many of the great themes of profounder inquiry he had thought much. It was to be regretted that at one time his mind took a too skeptical turn. It does not appear, however, that he ever surrendered his belief in the verities of the Christian religion, and during his long illness he showed excellent evidence of a calm and steady faith in God, and of a patient resignation under the afflictive orderings of the divine will.

"He made a heroic struggle for life. He was ambitious, and greatly desired to live to carry out his cherished and laudable plans. A few years more, he confidently felt, would be worth a great deal in fulfilling his life work and his heart's desires.

"But he studied carefully the nature of the malady against which he was contending, a disease of the throat, which for a long time did not much affect his general strength, and at length he became convinced that before long it would put a period to his life. In his boyhood, I have heard, if he met with any great disappointment, it was not his way to say anything, but to go away by himself with an axe or a spade, and work off his feelings by violent exercise.

"And so he told me, when he at last reached the conclusion that it was only a question of a few months when he must die, he said nothing, but went down into the cellar alone and violently assaulted the stone wall until he was thoroughly tired out. Then he could talk calmly of the prospect before him. As his disorder advanced, his difficulty in taking food increased. He was literally starving to death. It was pitiful to see the signs of a hunger which he could not gratify.

"He used to take long walks, and a strange fascination led him to frequent the public markets and to feast his eyes, at least, on the abundant and tempting display of numberless varieties of food. Once, he told me, he really envied Dr. Phillips Brooks. He chanced one day to see him at the Boylston Market take up a big apple and bite out nearly half of it at one bite, and eat it down with evident relish. Poor man! he could hardly swallow a few drops of the blandest liquid. To the end, however, he was patient and serene, speaking freely—and who that heard him can forget his earnest whispered tones—of the mysterious future and of the spirit in which he was going forth to meet it.

"A high-minded man of unblemished integrity, genial, affectionate and true, his many friends cherish his memory with loving esteem."

I believe we may say of Mr. Lunt, as an engineer, that he was *honest* and *honorable* every way. It is said, "an honest man is the noblest work of God." I think it may truly be said an *honest engineer* is the noblest work of God. A dishonest engineer is a contradiction in terms. The two words sometimes *get* together, through the force of circumstances and great temptations, but they do not *belong together*, and wont *stay* together permanently. A dishonest engineer is a wolf in sheep's clothing, a devil in the form of an angel, a nothing, a zero, a zero removed a thousand places to the right from the decimal point, if that can diminish the value of a nothing. The engineer has placed in his hands the expenditures of vast amounts of money and the construction of works, which in numberless ways involve the lives, the property and the comfort of the community. He is trusted, as a matter of course. If he is false to his trust, no words of language, no expressions, of whatsoever sort, can sufficiently or fully express the contempt in which he should be held by his fellowmen. He should be spurned from business and social life and suffer perpetual professional banishment. He should commit professional hari kari and get out of the way.

THOMAS DOANE, Committee.

MEMOIR OF THEOPHILUS E. SICKELS.

HONORARY MEMBER BOSTON SOCIETY CIVIL ENGINEERS, MEMBER AMERICAN SOCIETY CIVIL ENGINEERS.

BORN 1822, DIED FEBRUARY 4, 1885.

The following is copied from the Proceedings of the American Society for November, 1885, page 130 :

Theophilus E. Sickels was a son of Dr. John Sickels, an old New York citizen, member of the Cholera Commission of that city during 1828–32, and afterwards Medical Inspector of the city ; an ardent politician, an original thinker, and a man of large reading and marked ability. Mr. Sickels received an academical education, and, like his father, was a classical scholar, although particularly excelling in mathematics and physical science.

He entered his profession in 1839 at the age of 17, as an assistant in the construction of the Croton Aqueduct, under Mr. John B. Jervis, Hon. M. Am. Soc. C. E. Subsequently he was engaged upon the Erie Railway, upon the enlargement of the Erie Canal and upon the Bear Mountain Railway. From 1848 to 1856, he was a resident engineer upon the Boston Water-Works.

He was also engaged upon the construction of the United States Dry Dock at Brooklyn, and in 1852 was the Chief Engineer of the Philadelphia & Westchester Railroad. From 1855 to 1857 he was the Chief Engineer of the Philadelphia & Baltimore Central Railroad ; 1857 to 1860 Chief Engineer and General Superintendent of the Hannibal & St. Joseph Railroad. Subsequently he was engaged upon the construction of the bridge over the Harlem River at Third avenue, New York. In 1868 he became the Chief Engineer and General Superintendent of the Union Pacific Railway, resigning that office in 1874, but retaining so greatly the confidence of the management, that he held the position of its consulting engineer at the time of his death.

In 1874 he was designated by the President, General Grant, as his personal choice, as one of the commission of seven engineers to consider and recommend to Congress the proper method for securing an open mouth to the Mississippi River. In the performance of this duty Mr. Sickels visited Europe, and joined in the report upon which the action of Congress was based, resulting in the notable improvement of the South Pass. Mr. Sickels was an earnest advocate of the jetty system.

In 1876 Mr. Sickels was one of the judges of the Centennial Exposition in Philadelphia, and in 1878 was the representative of the American Society of Civil Engineers at the Paris Exposition. He was afterward connected as chief or consulting engineer with various enterprises in different parts of the United States, and at the time of his death was the consulting engineer of the South Pennsylvania Railroad. In an inspection of one of the tunnels in course of construction on that road, he inhaled the fumes from an explosion, from the effects of which he never recovered.

Mr. Sickels built the Omaha bridge of the Union Pacific Railway, one of the earliest constructions with iron tubular piers. He was at the time of his death constructing a bridge over the Arkansas at Little Rock.

Mr. Sickels' large experience in the United States was supplemented by frequent visits abroad. His wide and accurate professional knowledge, his cultivated judgment, and the great personal purity of his character, made him the adviser and trusted counselor of many of the men who have had to do with the great undertakings in public works in the United States for many years past. Although constantly connected with active and important engineering works, Mr. Sickels manners were very modest and unpretending, and only when he became ardent in the discussion of professional topics, would one appreciate the range of his knowledge and his power of concise and luminous expression. Mr. Sickels' home was at Kennett Square, Chester County, Pa., where he had a delightful residence. He retained, however, his professional office in New York up to his decease. He was a widower, and leaves but one daughter. Mr. Sickels was elected a Member of the American Society of Civil Engineers, February 21, 1872.

This ends the quotation from the memoir of the American Society, which does not need the indorsement of this Society, and for which it is in no way responsible.

Mr. Leavitt Burnham, of Omaha, for many years Land Commissioner of the Union Pacific Railway Co., writes to me as follows concerning Mr. Sickels :

"He came here about 1868 or 9 to direct the building of the Missouri River Bridge, which, being then, I believe, the second structure only of its kind in the U. S., if not in the world, claimed and received especial skill, ingenuity and fertility of resource.

"After its completion he acted for several years as General Superintendent of the Union Pacific, and has, I think, subsequently and until near his death been their consulting and advising engineer, especially in matters outside routine or established character.

"His marked characteristic was his ability to fill just such places, and his strong good sense and *independent original* judgment made him successful where others failed, by not venturing, or lacking power, fertility and energy to go forward if they did. This was particularly illustrated in case of the bridge, which was constantly criticised, but by its effectiveness, strength and durability has justified all his decisions and direction concerning it. (As to its structural style, you are of course familiar.)

"He was a person well poised, cool, calm, equal to emergencies, but not given to egotism, temper or unhappy ways of asserting himself.

"He was genial, happy and agreeable in intercourse and a most pleasant conversationalist and companion, a deep reader and close observer.

"I am unable to give facts and dates concerning his chief works."

Mr. C. S. Stebbins, of Omaha, General Ticket Agent of the Union Pacific Railway, says of Mr. Sickels

"While I enjoyed a personal acquaintance with Mr. Sickels from my boyhood, my knowledge of his business career was confined to the period extending from 1870 to 1874, during which time he had charge of the Missouri River Bridge at Omaha, as Chief Engineer and Superintendent, and was also General Superintendent of the Union Pacific Railroad.

"His skillful management of the latter demonstrated what up to that

time had been regarded as very doubtful, that the property could be operated so as to pay not only current expenses, but interest on all its obligations and finally handsome dividends.

"In 1854, while serving as Engineer of the Philadelphia & Baltimore Central Railroad, now a portion of the Pennsylvania system, he made the acquaintance at Kennett Square of Miss Lydian Taylor, a member of an old and honored family that has produced several distinguished men of more than local reputation, and a year later married her, and established his residence at Kennett Square, which remained his home until his death. His wife and one daughter died in 1876. One daughter, now a young woman, survives him.

"Mr. Sickels was distinguished by the simplicity and abstemiousness of his personal habits, the warmth of his domestic affection, his social nature, his enjoyment of life, his ready sympathy and his active and unostentatious charity, the extent of which was never known except to himself and to its recipients, unless divulged by accidental circumstances. The death of few men is mourned with a sense of personal loss by so wide a circle of friends unconnected by ties of relationship or interest."

While Mr. Sickels was Engineer of the contractor building the Hannibal & St. Joseph Railroad, he was known to one of your Committee, Mr. Vose, who indorses all that has been said concerning Mr. Sickels' ability, experience, and social character.

Mr. Doane, of your Committee, made the acquaintance of Mr. Sickels at Omaha, in 1869. The Missouri River Bridge was then under construction. As nearly as I remember it was attempted to sink the tubes of the piers by the "open to the air" process, but the pneumatic process was resorted to. Much difficulty was experienced in sinking the tubes vertically in the swift current and treacherous bottom of the Missouri River. That part of the tubes below surface was of cast iron, and the parts above were of wrought iron. The tubes when sunk to the bottom were filled with layers of about two feet of broken stone, which were then grouted. As some of this work was done in very cold weather, salt was mixed with the grout to prevent freezing. The tubes filled in summer, afterwards burst in some places, probably because the method of grouting filled the tubes so tightly that there was no opportunity for the iron shell to contract in cold weather without parting the iron vertically. These tubes were afterwards hooped.

The bridge was for a single track and about 50 feet above the river. There were two tubes in each pier, which went down to an extreme depth of about 85 feet.

In some way never fully understood the easterly span of the bridge fell. It was probably thrown down by a cyclone.

The increase in weight of rolling stock, in the volume of traffic and the demand of Omaha and Council Bluffs for a connecting highway, has made it necessary to build a new double track bridge carrying the highway, which is now approaching completion. The new bridge occupies the same site as the old one, but is set on new stone piers.

The old bridge has done its work in a very satisfactory way for about 17 years.

I last met Mr. Sickels at Charleston, West Virginia, in 1881, when he

was looking over some proposed railroad locations across the mountains between the Monongahela and the Elk and Kanawha rivers.

Our intercourse was always pleasant.

Mr. Sickels became a member of the Boston Society of Civil Engineers, July 3, 1848, which was the date of its organization, and was therefore an *original* member, being at the time engaged upon the construction of the Boston Water-Works.

GEORGE L VOSE, }
THOMAS DOANE, } Committee.

ANCHORAGE OF SUSPENSION BRIDGES.

By CARL GAYLER, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read March 16, 1887.]

The method of anchoring suspension bridges is well known : The ends of the main cables are secured to massive stone piers by means of chains extending into the interior of these piers and fastened to heavy iron plates. These latter are located so that the thrust of the cables imparted to the chains is resisted by as great a portion of the weight of the piers as possible.

A somewhat different arrangement we find in the case of a few suspension bridges built in France, where the principal tensile members of the bridge, instead of ending at and being attached to large bed plates, pass around the anchor piers, thus forming a continuous line over the whole length of the bridge. Aside from this peculiar arrangement, the designs of anchor piers not only vary according to the locality, the dimensions of the structure and the views of the engineer, but we can also easily distinguish two systems radically different from each other in the manner in which the iron work inside of the piers is protected against corrosion.

Under the first system, chambers or tunnels, drained at their lower ends, are left in the masonry around the full length of the anchorage, so that the latter is as accessible as any part of the superstructure, and can be inspected and painted. In anchor piers built in this manner there is generally also provision made for free expansion and contraction of the iron.

Taking a diametrically opposite view of the requirements of the case, the engineer who designs the anchor piers according to the second system has the ironwork, from the point where it enters the pier down to the anchor plate, surrounded by masonry, and carefully imbedded in hydraulic cement mortar.

This latter system has been universally adopted in our country, and it is the object of this paper to point out its defects, defects which cannot only be clearly demonstrated, but which have also shown themselves in the course of years that our suspension bridges have been in use.

The first question which presents itself, whether iron, imbedded in cement, is completely protected against corrosion, can, from the experience gained with two old suspension bridges in Pittsburgh, and with the foundations of the Niagara bridge, be answered in the affirmative, and there can indeed be no reason for doubting that hydraulic cement, after

the chemical process of hardening is ended, acts as an air-tight, impervious coating. During that process the painting of the iron can reasonably be supposed to form a sufficient protection against any chemical action between the wet cement and the surface of the metal. But supposing this question to be finally decided in favor of our system, there is still the condition to be fulfilled that the close contact between the metal and the cement remains undisturbed, as otherwise the access of air and dampness is unavoidable. How far this condition of a perfectly undisturbed position of each member of the anchorage is at variance with our present system of securing the anchorage we will now examine.

The anchor piers of all suspension bridges in this country are built on the same pattern, they only vary in size, not in character. The anchor plate holds the ends of the last tier of eye-bars by means of a pin, the different tiers of eye-bars form near the anchor plate a vertical line from which they gradually diverge, so that each consecutive tier forms with the preceding one a certain angle, until the last eye-bars hold either the strands of the cables or connect with the principal members of the superstructure. At each joint where an angle is formed, the heads of the eye-bars rest on an iron plate and dimension stones.

We have now to keep in view the circumstance that the anchor piers are completed before work on the superstructure can be begun, and that the iron inclosed by the pier has been put in position without any initial strain whatever. In case the bridge is carried by cables composed of wires, there is generally an interval of months, even years, before the completion of the superstructure.

With the progress of the erection the strain is gradually applied to the anchor chains until, after the completion of the work, the whole weight of the superstructure and the additional pull produced either by railroad trains or by the traffic of some large city are brought to bear on the anchorage. The effect will be as follows: Supposing the end anchor plate and pin to be close up against their bearing, a stretching of the anchor chains will take place, gradually increasing in direct proportion to the distance from the end pin. (For a strain of 10,000 pounds to the square inch this elongation amounts to about one-sixteenth of an inch in twelve feet.) To this movement has to be added the play of each pin in the pin hole. The strain in the iron changes in intensity under the moving loads of the bridge, but in the last tier of eye-bars, in those which connect directly with the superstructure, not only its intensity, but also its direction, varies. These bars are, therefore, not only pulled lengthways, but are moved up and down also.

As the anchorage is imbedded in the stonework, we will not take in consideration the effect of temperature, although in that part of the ironwork which is near the outside of the pier, its effects certainly add to the movements indicated above.

In order to see clearly the result of the movements of the ironwork inside of the pier, impeded as they are by the inclosure of mortar and masonry, we will, for a moment, consider the following two extreme suppositions: 1. That the iron moves freely according to the laws of elasticity. 2. That the masonry prevents any such movements. Under the first supposition, the contact between the iron and the cement is broken, a crack

all along the iron is started, widening toward the outside, access is made for damp air and the influences of changing temperatures. As the bars stretch, their heads with their pins are pulled forward in a direction corresponding to the curvature of the anchorage, thus causing a bending of the eye-bars edgeways and, owing to the resistance at the bearing of the heads, bending strains in the latter also. Besides exposing the iron to corrosion, fibre strains have been produced in addition to those for which the anchorage has been designed.

If, on the other hand, we suppose that the mortar and the stonework effectually resist the movements of the ironwork, we have to accept the following conclusions : Aside from the friction between the surfaces of the eye-bars and the mortar, the principal resistance is formed at the joints, the increased width of the heads over the bars, the ends of one set of eye-bars and the nuts of the pin forming an actual surface against the hardened hydraulic cement mortar and the stonework. There is, therefore, the novel duty imposed on the eye-bar heads of dividing their work between transferring the strains of one set of bars to the following one and acting for the pin as bearings on the masonry. It is also easy to see that the resistance at the joints is larger toward the end of the pins than at the centre, which fact produces an increased bending moment in the pin and has a different effect on the different eye-bar heads. Enlarging the size of the pin would be an easy matter, but, as it is a well-known fact that the weak part of an eye-bar is its head and that an increase of the metal in the head does not insure a correspondingly greater strength, it is not justifiable to cause in these heads additional fibre strains hard to define in their nature and extent.

The actual condition inside of the anchor pier can reasonably be supposed to be a compromise between the two extreme suppositions which we have just considered, and can be summed up as follows :

First. The close contact between the ironwork and the hydraulic cement mortar is broken and corrosion will set in sooner or later.

Second. The different parts of the ironwork are subjected to internal strains for which they have not been proportioned, and the intensity and directions of which are extremely difficult to ascertain.

The above considerations may appear to many of not sufficent importance to warrant a complete change of the system of our anchorages, but there is nothing unimportant in engineering. If we look back, what changes have taken place in the designs of bridges during the last 20 years, brought about principally by taking into account strains which no engineer formerly considered important enough to be taken into consideration? Who thought 15 years ago of calculating bending moments in pins or the web bearing of rivets, and yet what changes have been wrought in our details through these seemingly "unimportant things." In view of the faithful and conscientious work of our bridge builders we can only wonder that this most important part of our suspension bridges has been, and is being up to date, built in the same primitive, not to say reckless, manner as in the first suspension bridge built 40 or 50 years ago.

The points stated above are confirmed by the following facts which appeared after careful examination of the anchorage of the Niagara bridge.

1. Nearly all the pins were found to be bent convex towards the cables in some cases the convexity amounted to $\frac{5}{16}$ of an inch in the total bearing length.

2. The curved positions of all chains had settled forward towards the river and downward, leaving cavities between the cement and upper edges of the links and back of the pins. The cavities were largest at the upper joints, and nearly disappeared about the third joint down. The portion of the metal thus exposed had a thin coating of rust.

3. A number of the outer wires of the end strands had to be cut out and replaced—mostly those of the outer strands. All inner wires were found to be as clean and smooth as when first put in.

Colonel Paine and L. L. Buck, the engineers in charge of this examination, say in their report in regard to the condition of the wires: "The evident cause of the corrosion was the elongation and contraction of the wires of the strands, due to loads passing upon and off from the bridge, thereby loosening the wires from the cement, thus admitting moisture, which gradually worked down to the lowest point. The portion of the cement among the strands would go and come with the strands themselves, thus excluding the moisture."

An investigation into the condition of the anchorage of the St. Clair bridge across the Allegheny River at Pittsburgh, made shortly after the floor of that bridge had been destroyed by fire, showed the wire strands, which had been imbedded in the masonry, to be in a condition similar to that of the end strands of the Niagara bridge. It was found necessary to cut out and replace a great number of the wires.

In this work of reconstruction the end strands have been left accessible, a step in the direction which I have tried to indicate in this paper.

PROGRESS OF METALLURGY IN 1886.

Extract from a Paper by Geo. W. Goetz, Member of the Civil Engineers' Club of Cleveland.
[Read January 25, 1887.]

The time at my disposal will permit me to mention only the most important improvements in metallurgy, and I shall therefore confine myself to the metal magnesium and its oxide, and the latter's application to the manufacture of very soft steel.

Improvements in the working of nearly all the metals have been made.

In 1884 the price of magnesium in New York was quoted at $50 per pound in the price lists of the chemical companies, but it can now be bought for about $5 per pound. It is manufactured on a large scale by a firm in Hanover by electrolysis, using the waste chloride of magnesium of the Stassfurt mines in Northern Germany.

Besides various uses in the chemical industry to replace finely divided zinc as a reducent, it is mainly used for light and to make nickel ingots solid. The ocean steamers use considerable of the metal for signals and when entering port at night.

A torch containing magnesium is now used abroad for processions, which we will probably see during our next campaign here. A pure

nickel ingot is very honeycombed, but by the addition of only about $\frac{1}{2}$ per cent. of magnesium a perfectly sound ingot is obtained. Nickel ingots can now be rolled into thin sheets and can be welded to iron. Such nickel-covered sheet iron is now used extensively for the manufacture of household goods. This material wears better than electro-plated ware, and, as nickel is very hard, it will stand any amount of hard rubbing to keep it bright without any danger of it wearing away.

But the principal improvement is the use of oxide of magnesium for the manufacture of soft steel out of materials, which heretofore could not be used for the manufacture of steel, such as pig iron with phosphorus higher than contained in ordinary Bessemer pig and general mixed scrap, and to produce therefrom a material with less than 0.040 per cent. of phosphorus and other constituents as desired.

So much has been written on the basic process for the manufacture of steel out of phosphoric pig, that I shall not attempt to make a detailed description of this process, but in order to show you the advantages to be derived by the use of magnesia for furnace linings, a short description of the basic process will help you to more easily understand the matter. Dolomite or limestone is subjected to a very high heat generally in a cupola, so that the material will not only lose its carbonic acid, but will change its molecular condition so much that when a piece is moistened, it will not slack in the time ordinary burned limestone will, and furthermore, it must have been heated so highly that when it is subjected to a high heat in a process, it will not shrink in volume.

This material is crushed, mixed with tar free from ammonia and water, and is then ready to be rammed in as a lining for a Bessemer converter or on the hearth of a steel melting furnace. As soon as the lining has been rammed, it is heated up to coke the tar, the coke acting as a binder for the shrunk material. As soon as the lining is ready and heated up, from 14 to 20 per cent. of burned lime is added, and then the pig iron is charged and the converter erected to be blown. As soon as the carbon is nearly all eliminated, the so-called afterblow takes place, during which period the phosphorus is eliminated. As soon as the desired amount of dephosphorization has taken place, the slag is poured off by tipping the converter slightly, and then after the addition of ferromanganese the steel is poured into a ladle and cast into molds.

Heretofore the slag was poured off from the charge at the end of the process, but lately some of the Westphalian works pour off the slag when the bulk of the phosphorus has been removed, and then add fresh lime to remove the last low percentages. This manipulation is a decided improvement; it not only dephosphorizes more effectually, but it also gives a slag more suitable for agricultural purposes than when the whole quantity of slag is carried to the end of the process. There are very many interesting facts connected with this subject, which I cannot mention at present.

The pig iron used for the process must be as low as possible in silicon, in order to protect the basic lining and in order to be able to easily produce a highly basic slag, for Mr. Hilgenstock, of Hörde, has shown that for successful dephosphorization the constitution of the slag must be so that a tetraphosphate of lime can easily form. As the silicon is very

low in the pig iron, and as it is the heat-giving element in the Bessemer process, some other heat-giving element must be present in such a quantity that sufficient heat is generated to carry through the blow and to cast the ingots. This is the reason why about 2 per cent. of phosphorus is desired in basic pig iron. Pig iron containing 2 per cent. of phosphorus, from 1 to 2 per cent. of manganese and silicon, and sulphur as low as possible, is not very plentiful here, and when we consider the extra expense for refractories and labor connected with the basic process, and the large supply of low phosphorus ores in the country, it will probably be a long time yet before the basic Bessemer process will be carried out here to such an extent as it is abroad.

The basic open-hearth process, though, seems to have quite a future at present, because one is not bound to any special composition of the raw materials. Pig iron, regardless of the percentage of phosphorus it contains, can be used; brands which contain too much phosphorus for the acid Bessemer process and not enough for the basic Bessemer, especially those containing from 0.20 to 0.50 per cent. of phosphorus, which can be produced cheaper than Bessemer pig, and, what is the most important, a large amount of miscellaneous scrap is used, of which there is a large amount in the country, especially in the West. These materials are charged into a furnace having either a lining made out of shrunk dolomite, magnesia or chrome ore. As soon as the charge is melted the slag is drawn off with broad hooks; fresh lime is then charged on the melted metal, which is again removed. This manipulation is repeated until the metal has been dephosphorized to the desired extent; ferromanganese is then added and casting commenced. Where there is a basic Bessemer plant, the basic open hearth with dolomite is the most economical, because freshly shrunk dolomite can always be obtained from the Bessemer works; but where this is not the case, magnesite or chrome is preferred.

After calcination, the magnesia can be stored for a long time, whereas shrunk dolomite must be used fresh.

The magnesite has the remarkable property not to flux with the silica sides of a furnace, whereas shrunk dolomite must be separated from any silicious parts of the furnace by a layer of magnesia or chrome ore.

A magnesia brick can be placed into direct contact with a silica brick without any fluxing taking place. This property of magnesia and chrome to allow a lining of them to lie up against a silicious lining and at the same time to resist the corrosive action of a highly basic slag is highly important for the manufacture of soft steel, out of materials which could not be utilized in a furnace lined with sand, on account of the variable amounts of phosphorus the product would have.

Magnesia is also one of the most powerful refractories we have. I have placed a piece of the calcined mineral in the hottest part of a Siemens steel melting furnace without having any melting effect on it whatever. Nearly all the wire works of the country have tried soft basic steel, and can attest its extreme softness, and the consequent larger reductions possible in afterwards drawing the same.

The process is at present in operation in Germany for soft wire rods, and in France for rods and sheets, where I have had occasions to study

the process; it is also in operation in Russia for rails out of scrap, which has accumulated in Russia, and which scrap contains too much phosphorus to otherwise work it up.

The basic steel is the nearest thing to metallic iron which has as yet been produced.

The process is not covered by patents. Emil Muller took out patents in 1869 on a lining made of magnesia and basic additions for the purpose of dephosphorization. These patents have expired. At that time they had not been successful in making a lining, because no matter how highly the magnesia was heated, the material remained in a pulverulent form; the magnesia employed was too pure. Recently, however, large deposits of magnesite have been discovered in Styria, which has a small percentage of silica, lime, alumina and iron, just sufficient to cause a lining as described to stick together. The process is out of its experimental stage, as many tons of soft steel low in phosphorus are being produced, and there seems to be no doubt but that the magnesia process will soon be an important addition to our great steel industry.

CHAPIN WROUGHT IRON; AND FOUNDATIONS OF THE CENTRAL VIADUCT, CLEVELAND, O.

SEMI-ANNUAL REPORT OF THE COMMITTEE ON CIVIL ENGINEERING AND SURVEYING, OF THE CIVIL ENGINEERS' CLUB OF CLEVELAND, O. BY W. H. SEARLES, CHAIRMAN OF THE COMMITTEE.

[Read February 22, 1887.]

NOTE.—The reports upon the subject of Steel Tapes, by Messrs. Varney and Culley, will appear in a subsequent number of the JOURNAL.

Notwithstanding the wonderful development of our steel industries in the last decade, the improvements in the modes of manufacture, and the undoubted strength of the metal under certain circumstances, nevertheless we find that steel has not altogether met the requirements of engineers as a structural material. Although its breaking strain and elastic limit are higher than those of wrought iron, the latter metal is frequently preferred and selected for tensile members, even when steel is used under compression in the same structure. The Niagara cantilever bridge is a notable instance of this practice. When steel is used in tension its working strains are not allowed to be over fifty per cent. above those adopted for wrought iron.

The reasons for the suspicion with which steel is regarded are well understood. Not only is there a lack of uniformity in the product, but apparently the same steel will manifest very different results under slight provocation. Steel is very sensitive, not only to slight changes in chemical composition, but also to mechanical treatment, such as straightening, bending, punching, planing, heating, etc. Initial strains may be developed by any of these processes that would seriously affect the efficiency of the metal in service.

Among the steels, those that are softer are more serviceable and reliable than the harder ones, especially wherever shocks and concussions or rapidly alternating strains, are to be endured. In other words, the

more nearly steel resembles good wrought iron, the more certain it is to render lasting service when used within appropriate limits of strain. Indeed a wrought iron of fine quality is better calculated to endure fatigue than any steel. This is particularly noticeable in steam hammer pistons, propeller shafts, and railroad axles. A better quality of wrought iron, therefore, has long been a desideratum, and it appears now that it has at last been found.

Several years since a pneumatic process of manufacturing wrought iron was invented and patented by Dr. Chapin, and an experimental plant was erected near Chicago. Enough was done to demonstrate, first, than an iron of unprecedentedly good qualities was attainable from common pig; and second, that the cost of its manufacture would not exceed that of Bessemer steel. Nevertheless, owing to lack of funds properly to push the invention against the jealous opposition which it encountered, the enterprise came to a halt until quite recently, when its merits found a champion in Gustav Lindenthal, C. E., Member of this Club, who is now the General Manager of the Chapin Pneumatic Iron Co., and under whose direction this new quality of iron will soon be put upon the market.

The process of manufacture is briefly as follows: the pig metal, after being melted in a cupola and tapped into a discharging ladle, is delivered into a Bessemer converter, in which the metal is largely relieved of its silicon, sulphur, carbon, etc., by the ordinary pneumatic process. At the end of the blow the converter is turned down and its contents discharged into a traveling ladle, and quickly delivered to machines called ballers, which are rotary reverberatory furnaces, each revolving on a horizontal axis. In the baller the iron is very soon made into a ball without manual aid; it is then lifted out by means of a suspended fork and carried to a Winslow squeezer, where the ball is reduced to a roll twelve inches in diameter. Thence it is taken to a furnace for a wash heat and finally to the muck train.

No reagents are employed, as in steel making or ordinary iron puddling. The high heat of the metal is sufficient to preserve its fluidity during its transit from the converter to the baller; and the cinder from the blow is kept in the ladle.

The baller is a bulging cylinder having hollow trunnions through which the flame passes. The cylinder is lined with fire-brick, and this in turn is covered with a suitable refractory iron ore, from eight to ten inches thick, grouted with pulverized iron ore, forming a bottom, as in the common puddling furnace. The phosphorus of the iron, which cannot be eliminated in the intense heat of the converter, is, however, reduced to a minimum in the baller at a much lower temperature and on the basic lining. The process wastes the lining very slightly indeed. As many as sixty heats have been taken off in succession without giving the lining any attention. The absence of any reagent leaves the iron simply pure and homogeneous to a degree never realized in muck bars made by the old puddling process. Thus the expense of a reheating and rerolling to refine the iron is obviated. It was such iron as here results that Bessemer, in his early experiments, was seeking to obtain, when he was diverted from his purpose by his splendid discoveries in the art of making steel. So effective is the new process, that even from the poorest

grades of pig, may be obtained economically an iron equal in quality to the refined irons made from the best pig by the ordinary process of puddling.

Numerous tests of the Chapin irons have been made by competent and disinterested parties, and the results published. The samples here noted were cut and piled only once from the muck-bar.

Sample A was made from No. 3 mill cinder pig.

Sample B was made from No. 4 mill pig, and No. 3 Bessemer pig, half and half.

Sample C was made from No. 3 Bessemer pig, with the following results:

Sample.	A.	B.	C.
Tensile strength per sq. in.	56,000	60,772	64,377
Elastic limit	34,000	....	36,000
Extension, per cent	11.8	....	17.0
Reduction of area, per cent	65.0	16.0	33.0

The tensile strength of these irons made by ordinary puddling would be about 38,000, 40,000, and 42,000 respectively, or the gain of the iron in tensile strength by the Chapin process is about fifty per cent. Not only so, but these irons made in this manner from inferior pig show a higher elastic limit and breaking strain than are commonly specified for refined iron of best quality. The usual specifications are, for refined iron: Tensile strength, 50,000; elongation, 15 per cent.; elastic limit, 26,000; reduction, 25 per cent.

Thus the limits of the Chapin iron are from 12 to 20 per cent. above those of refined iron, and not far below those of structural steel, while there is a saving of some four dollars per ton in the price of the pig iron from which it can be made. When made from the best pig metal its breaking and elastic limits will probably reach 70,000 and 40,000 pounds respectively. If so, it will be a safer material than steel under the same working strains, owing to its greater resilience.

Such results are very interesting in both a mechanical and economical point of view. Engineers will hail with delight the accession to the list of available building materials of a wrought iron, at once fine, fibrous, homogeneous, ductile, easily weldable, not subject to injury by the ordinary processes of shaping, punching, etc., and having a tensile strength and elastic limit nearly equal to any steel that could safely be used in the same situation.

A plant for the manufacture of Chapin iron is now in course of erection at Bethlehem, Pa., and there is every reason to believe that the excellent results attained in Chicago will be more than reached in the new works.

Foundations of the Central Viaduct of Cleveland, O.

The Central Viaduct, now under construction in the city of Cleveland, is probably the longest structure of the kind devoted entirely to street traffic. The superstructure is in two distinct portions, separated by a point of high ground. The main portion extending across the river valley from Hill street to Jennings avenue is 2,840 feet long on the floor line, including the river bridge, a swing, 233 feet in length; the other portion, crossing Walworth Run from Davidson street to Abbey street, is 1,093 feet long. Add to these the earthwork and masonry approaches, 1,415 feet long, and we have a total length of 5,348 feet. The width of

roadway is 40 feet, sidewalks 8 feet each. The elevation of the roadway above the water level at the river crossing is 102 feet. The superstructure is of wrought iron, mainly trapezoidal trusses varying in length from 45 feet to 150 feet. The river piers are of first-class masonry on pile and timber foundations. The other supports of the viaduct are wrought-iron trestles on masonry piers, resting on broad concrete foundations. The pressure on the material beneath the concrete, which is plastic blue clay of varying degrees of stiffness mixed with fine sand, is about one ton per square foot.

The Cuyahoga Valley, which the viaduct crosses from bluff to bluff, is composed mainly of blue clay to a depth of over 150 feet below the river level. No attempt is made to carry the foundation to the rock. White oak piles of from 50 to 60 feet in length and 10 inches in diameter at small end are driven for the bridge piers either side of the river bed, and these are cut off with a circular saw 18 feet below the surface of the water. Excavation by dredging was made to a depth of 3 feet below where the piles are cut off to allow for the rising of the clay during the driving of the piles. The piles are spaced about 2 feet 5 inches each way, centre to centre. The grillage or platform covering the piles consists of 14 courses of white oak timber 12 inches by 12 inches, having a few pine timbers interspersed so as to allow the mass to float during construction. The lower half of the platform was built on shore, care being taken to keep the lower surface of the mass of timber out of wind. The upper and lower surfaces of each timber were dressed in a Daniels planer and all pieces in the same course were brought to a uniform thickness. The timbers in adjacent courses are at right angles to each other. The lower course is about 58 feet by 22 feet, the top course about 50 by 24 feet, thus allowing four steps of one foot each all around. The first course of masonry is 48 feet by 21 feet 8 inches ; the first course of battered work is 41 feet 8½ inches by 16 feet 3 inches. Thus the area of the platform on the piles is 1,856 square feet and of the first batter course of masonry 777.6 square feet, or in the ratio of 2.4 to 1. The height of the masonry is 78 feet above the timber, or 73½ feet above the water. The number of piles in each foundation is 312. The average load per pile is about 11 tons, and the estimated pressure per square inch of the timber on the heads of the piles is about 200 pounds.

To prevent the submersion of the lower courses of masonry during construction, temporary sides of timber were drift-bolted to the margin of the upper course of the timber platform, and carried high enough to be above the surface of the water when the platform was sunk to the head of the piles by the increasing weight of masonry.

The centre pier is octagonal, and is built in the same general manner as to foundations as the shore piers, but the piles are cut off 22 feet below water, and there are eighteen courses of timber in the grillage. The diameter of the platform between parallel sides is 53 feet, while that of the lower course of battered masonry is but 37 feet. The areas are as 2,332 to 1,147, or as 2 to 1 nearly. The pressure per square inch of timber on the heads of the piles is about the same as stated above for the shore piers. The number of piles under the centre pier is 483.

The risks and delays by this method of constructing the foundations

were much less, and the cost also, than if an ordinary coffer dam had been used. Also the total weight of the piers is much less, as that portion below a point about two feet below the water adds nothing to their weight.

The piles were driven with a Cram steam hammer weighing two tons, in a frame weighing also two tons. The iron frame rests directly upon the head of the pile and goes down with it. The fall of the hammer is about 40 inches before striking the pile. The total penetration of the piles into the clay averaged 27 feet. The settlement of the pile during the final strokes of the hammer varied from one quarter to three-quarters of an inch per blow.

There are 122 masonry pedestals, of which eight are large and heavy, carrying spans of considerable length. They will all be built upon concrete beds except a few near the river on the north side, where piles are required.

The four abutments with their retaining walls are of first-class rock-faced masonry. The footing courses are stepped out liberally, so as to present an unusually large bottom surface. They rest on beds of concrete 4 feet thick. The foundation pits are about 50 feet below the top of the bluffs and are in a material common to the Cleveland plateau, a mixture of blue sand and clay, with some water. The estimated load of masonry on the earth at the bottom of the concrete is one and seven-tenths tons to the square foot. Two of the large abutments were completed last season. They show an average settlement of three-eighths of an inch since the lower footing courses were laid.

The facts and figures here given regarding the viaduct were kindly furnished by the City Civil Engineer, C. G. Force, who has the work in charge.

SOME NOTES ON MUNICIPAL PUBLIC WORKS.

By Thomas Appleton, Member of the Boston Society of Civil Engineers.

[Read February 16, 1887.]

This paper treats of the methods of defraying the expense and assessing the cost of public improvements in cities in the West, with which the writer is familiar. Some cities have saddled themselves with heavy loads of debt, incurred in making improvements more rapidly than their circumstances warranted, and have been compelled to make a radical change of methods and peremptorily stop the issue of bonds for public improvements. Kansas City, in its early days, like many other Western cities, issued bonds with a reckless prodigality for public improvements and in aid of railroads. It was found necessary to forbid the increase of debt for any purpose. The charter under which it has been governed for the past few years forbids the appropriation of a single dollar for any purpose unless the money is actually in the treasury at the time. It has been found necessary, therefore, to assess the entire cost of improving streets, building sewers, etc., upon the property benefited. The grading, curbing and paving of streets is assessed directly upon the abutting property in proportion to its frontage. The whole cost of the improvement, from end to end, including street intersection, is assessed upon

the property. Where the city owns a lot abutting on a street thus graded or paved, the city pays its special tax bill just the same as an individual owner. The city at large pays all the engineering and inspection expenses, but all work and material which can be done or furnished by a contractor is included in contracts which are awarded to the lowest bidder after proper advertisement. The contract and advertisement state expressly that the city will not pay for the work except by the issue of special tax-bills, which are a lien upon the property benefited.

Sewers, in that city, are paid for in the same manner, excepting that instead of assessing the cost upon the foot front it is assesessed upon the superficial area of each lot. The region to be sewered is divided into districts ; each district is such a portion of the city as can conveniently be drained by one main or sub-main sewer. Usually the whole system of sewerage for a district is not built at once, but portions of it are built from year to year as the circumstances demand. But any sewer built in a district, whether it is the main sewer or a remote lateral, is paid for by the lots in the whole district in proportion to their areas. All of these public improvements, sewers, sidewalks, curbing, paving, or grading, are paid for in special tax-bills, against the property benefited. These bills are a peremptory demand against the owner for the full amount of the cost of the improvement and bear interest at heavy rates from 30 days after the date of issue. Many of the owners are not prepared to meet this immediate demand, and the contractors are obliged to wait, sometimes for years, for the final payments. For this reason any contractor who does public work and takes his pay in tax-bills must have a bank behind him, and the capital and risk must be paid for, consequently the prices are usually high. If the contractors were paid promptly in cash the cost of the work to the property owner would be much less than it is under the present system.

In Chicago, and some other cities, the cost of any contemplated improvement is estimated by the City Engineer, assesssed upon the property benefited, and collected before the contract for the work is let. The estimates are generally made liberal, so as to be sure to cover the cost of the work, and no contract is awarded unless its total amount is less than the amount collected. After paying the contrator, the balance of this special tax collected, if any, is refunded to the property owners. By this method the whole cost of the improvement must be paid at once by the property owner. But, as the contractor is paid in cash, the prices would be usually smaller than where he is paid in special tax-bills, as in Kansas City.

The thriving young city of East Saginaw, Mich., has methods of conducting public work which commend themselves to those who are conversant with them. To digress a little from the subject of assessing and paying the cost of improvements, the methods of planning the work in East Saginaw will be discussed. The water-works are owned by the city, and the mains are extended and pumping works increased from time to time at the public expense. The sewerage system is planned in advance. A scheme of sewerage for the whole city has been made, adopted by the city council, and placed upon record in the county office. It cannot be changed without going through a considerable process of

"red tape." This is a wise provision, for the plans are carefully studied and devised for the most perfect sewerage of the whole city, and should not be subject to change by ignorant or officious councilmen.

When it is proposed to pave any street the first questions are; Has the street a sewer, and are the water main and gas main laid? Is there any filling of the street required to bring it to grade? The city council has an established and well-observed rule that no street shall be paved until after these improvements have been made. In the early summer a list of streets to be paved is determined upon. The Water Board is notified, and they proceed to put in service pipes from the main to the sidewalk line opposite every lot. The lot owners are notified to make sewer connections forthwith, and in case any lot owner fails to do so the city puts in a six-inch sewer pipe connection from the sewer to the sidewalk line opposite every lot, and the cost of this connection is assessed upon the property benefited and collected in the next tax roll. The gas company is also notified, and while they cannot be compelled to lay mains or put in service pipes, the company does as much of this work as it thinks is warranted by the circumstances. All this is done the year before the paving is commenced. By thus planning and executing the work in advance nearly all trenching or excavation of the street is done the year before the paving is executed. Trenches are carefully refilled, and they have the benefit of the rains and frosts to completely settle and campact the earth.

The most common style of pavement is composed of cedar blocks laid upon one inch boards, with three inches of river sand under the boards. The ground surface is carefully trimmed to conform to the shape of the roadway, and is thoroughly rolled with a steam road-roller. This work, when well done with a good quality of boards and cedar blocks, gives a smooth and durable pavement at a very small first cost. It is very rarely necessary to take up the pavement for the purpose of laying pipes of any kind. As an additional incentive to induce property owners to make their sewer and water connections in advance, the city requires that when a property owner desires to take up pavement for such purposes, he shall pay into the treasury not only the whole cost of taking up and restoring the pavement, which is estimated by the Superintendent of Streets, but also an additional penalty of $25 to cover the depreciation of the pavement in consequence of its being thus disturbed. The work of taking up and restoring the pavement is done by experienced men employed by and under the direction of the Superintendent of Streets.

The contracts for paving are usually awarded in the winter and the work commenced as early in the spring as the condition of the ground will allow. The contractors for paving and for building sewers are paid in cash weekly. Funds for these payments are provided by issuing city bonds, having five years to run, the amount to be issued in any one year and the total amount outstanding being limited by the terms of the city charter. Upon the completion of the season's work, the total cost of each improvement, either in paving or sewer construction, is eitimated by the Board of Public Works, and by them assessed upon the property benefited. This assessment, after being ratified by the council, is turned over to the City Assessor, who divides the total assessment upon each lot into

five parts, one-fifth of the total assessment, with interest on the remaining four-fifths is placed in the coming tax-roll, and collected with other taxes. The next year another fifth, with interest on the remaining three-fifths, is assessed and collected in the same manner. By this method the property owners need pay only a small portion of the entire cost at once, and the burden of expensive improvements is lightened. Consequently, petitions for sewers or paving are numerous, and the council is compelled each year to select from the number those cases which are of the most immediate importance. If the whole cost of such improvements were demanded at once, it is probable that petitions would be rare and remonstrances numerous. All public improvement sare done under the direction of a Board of Public Works, composed of five members, one of whom goes out of office each year. This Board is appointed by the Mayor, and the members serve without pay. The Board appoints the City Engineer and Superintendent of Streets. It should be added that the city at large pays for the cost of paving or grading all street intersections, and also pays for the excessive cost of large sewers. In estimating the amount to be assessed upon the property for building a sewer, the Board computes what would have been the cost of a twelve-inch pipe sewer for the distance in question, and this amount is assessed upon the property, the balance being paid for by the city at large. By this method the city of East Saginaw is enabled to have its public improvements made at the lowest prices, and it compares well with any city in the United States in point of condition of streets and sanitary improvements,

There may be other cities having equally good methods, but to the writer the East Saginaw way seemed to be unique and deserving imitation.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

APRIL 27, 1887:—A special meeting of the Boston Society of Civil Engineers was held and called to order at 8 o'clock P. M., President L. Fred Rice in the chair, thirty-one Members, five visitors present.

The President read the resignation of Secretary H. L. Eaton.

On motion it was voted : That a committee of five be appointed by the chair to nominate a Secretary to fill the vacancy occasioned by the resignation of H. L. Eaton.

The Chair appointed the following committee : Fred. Brooks, W. E. McClintock, D. FitzGerald, A. H. French, A. F. Noyes.

Professor W. S. CHAPLIN exhibited samples of rivets showing the poor character of the work done by one of the best bridge companies.

The speaker favored pin over riveted bridges.

Mr. C. H. PARKER discussed the difference between pin and riveted bridges, and called for a description of a pin bridge, described the improvements made in pin bridges and contended that there was not an existing bridge that could be called a perfect pin bridge. A modern bridge is a union of the good points of both pin and riveted bridges.

The imperfections in riveted bridges are due to work done on the site of the bridge, not that in the shop. Competitive letting of bridges was condemned.

Professor CHAPLIN stated that no bridge should be constructed before the plans had been submitted to a competent engineer for examination and be subject to inspection after erection. A State Bridge Commission should be organized and a law passed requiring that plans of bridges hereafter erected should be submitted to a competent engineer for examination, and be subject to rigorous inspection after erection and before being open to travel.

Mr. H. MANLEY agreed with the preceding speaker. Highway bridges should be subject to inspection as well as railway bridges. Any law passed or any steps taken must be very carefully considered so that no responsibility should be shifted from the railroads to the State.

Mr. FRED BROOKS : Among experts the opinion is gaining favor that there should be a Mutual Insurance Company for bridges, which should teach how to construct bridges as well as insure them.

Mr. MANLEY : The public have two safeguards in this matter. Heavy financial responsibility of railroads for injuries or death to its patrons by accident.

The pressure of public opinion as affecting the business and future prosperity of railroads.

Mr. PARKER favored an inspection of bridges similar to the English system of inspection of iron vessels. A standard should be fixed by legislation.

Prof. G. LANZA : No relief will be found without definite inspection. The speaker was not in favor of bridge insurance.

Mr. L. F. RICE : Effective action can be taken only by enforcing a heavy

penalty on railroad corporations. As long as the question of amount of damages remains low it will be simply a matter of insurance with railroads in this matter of accidents.

Mr. MANLEY: Officers of the Boston & Providence Railroad feel this matter with a great deal of keenness. While it may be necessary to condemn railroads, the important thing is the dissemination of engineering knowledge among railroad corporations.

On motion of Prof. W. S. Chaplin, it was voted that a committee, consisting of the President, Treasurer and Mr. E. S. Philbrick, be appointed to appear before a committee of the Legislature to-morrow, or on any date thereafter, to urge the importance of some action looking to the inspection and supervision of railway and highway bridges.

On motion it was voted: That the name of Prof. W. S. Chaplin be added to the committee appointed to appear before the Legislative Committee on Railroads.

Mr. Charles H. Parker gave a history of the Bussey Bridge.

[*Adjourned.*] H. L. EATON, Secretary.

MAY 18, 1887:—A regular meeting of the Boston Society of Civil Engineers was held at Room 27, Boston & Albany Railroad Station, Boston. The meeting was called to order at 7:45 P. M., Vice-President Stearns in the chair; 43 Members and 9 visitors present.

The record of the last regular meeting and of the special meeting of April 27 was read and approved.

Messrs. Lemuel Pope and William A. Favor were elected Members of the Society.

The following were proposed for membership:

Mr. Nelson Spofford, of Haverhill, recommended by G. E. Evans and A. W. Hunking.

Mr. George H. Barrus, of Reading, recommended by Henry Manley and E. H. Gowing.

The Committee appointed to nominate a Secretary reported the name of Mr. S. E. Tinkham, and upon a ballot being taken he was declared elected.

On motion of Mr. FitzGerald the following resolution was unanimously adopted:

Resolved, That the members of the Boston Society of Civil Engineers gratefully appreciate the faithfulness and ability with which Mr. Horace L. Eaton has discharged the duties of Secretary of this Society, and they tender him their best wishes for his prosperity.

The consideration of the report of the Committee on Weights and Measures, presented at the March meeting, was taken up, and on motion of Mr. Manley it was laid on the table until after the literary exercises.

Mr. FitzGerald read a letter from the General Secretary of the Council of Engineering Societies on National Public Works, inviting the Members of this Society to be present at the coming convention of all the societies.

Mr. P. H. Dudley was then introduced to the Society, and read a paper on "Woods, their Structure, Decay and Preservation," which was very fully illustrated by lantern views.

At the conclusion of the reading of the paper, a general discussion took place upon the various methods of preservation of timber, in which Messrs. Manley, FitzGerald, Adams, and C. F. Allen of the Society, and Mr. E. R. Andrews and Mr. Dudley participated.

Business being resumed, on motion of Mr. Fred. Brooks, the report of the Committee on Weights and Measures was taken from the table and accepted. On motion of Prof. Chaplin it was *voted* that the report and a discussion of the same by Mr. Brooks be printed and circulated among the Members of the Society.

Adjourned.] S. E. TINKHAM, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

MAY 4, 1887:—The Club met at Washington University, at 8:25 P. M., President Potter in the chair, and twelve Members present. The minutes of the last meeting were read and approved. The doings of the Executive Bommittee meeting on the 4th inst. were reported.

Col. E. D. Meier read a paper on "Evaporative Efficiency of Boilers," prefacing his remarks by the statement that he had been unable to complete his investigations, and asking that the present paper be considered as introductory to a more complete discussion which he hoped to be able to present later. Col. Meier spoke of the duty expected of steam generating apparatus, and the difficulties met with in reducing the results secured in tests to a common standard for comparison. Some suggestions were made looking toward a suitable standard of comparison. The values of various grades of fuels were touched upon. The relative merits of steel and iron for boiler construction were discussed, the conclusion being that it depended wholly upon proper precautions being taken to make sure that a suitable grade of material is secured. Prof. Potter, Prof. Johnson, Mr. Flad, Mr. Seddon and Mr. Wheeler took part in the discussion.

The President announced the Committee on Smoke Prevention as now constituted to be: W. B. Potter, E. D. Meier, H. B. Gale, C. F. White, W. H. Bryan and C. E. Jones. A paper by H. A. Wheeler, on the "Relative Economy of Machine and Hand Drilling," was announced for the next meeting.

[*Adjourned.*] WM. H. BRYAN, Secretary.

MAY 18, 1887: The Club met at 8:15 P. M., at Washington University, President Potter in the chair, twenty-one Members and two visitors present. The minutes of the last meeting not being at hand, their reading was postponed. The Executive Committee reported its meeting of May 18, recommending J. N. Judson and N. W. Eayrs for membership. They were balloted for and elected.

Mr. R. E. McMath, Chairman of the Committee on National Public Works, made a report stating that no recent progress had been made. On motion, the report was received and the Committee discharged. Mr. McMath was directed to remit to the Treasurer of the National Committee the funds in hand for that specific purpose, and to express to the officers of that body the sentiment of the Club on the subject—which is not favorable to further agitation of the matter at present.

Mr. H. A. Wheeler then read a paper on "The Relative Economy of Machine and Hand Drilling." The subject was carefully reviewed, and the various factors entering into the problem were explained and discussed. A comparison based upon results in St. Louis limestone quarries showed an economy of 20 per cent. in favor of the machine. A comparison of work at the Conglomerate mine showed, in drifting, 5 per cent. in favor of the machine, but in sinking, handwork showed a superiority of 20 per cent. The comparisons were made upon the relative cost per foot of hole drilled, and did not include the factors of quantity of material removed, speed required and ventilation. The value of each of these factors could only be determined by an investigation into the special requirements of each case. They should always receive attention as they have an important bearing on the problem.

The discussion was participated in by Messrs. Holman, Melcher, Seddon, Moore, Potter and Stockett.

The question of the relative cost of mining coal by machine and by hand was also brought up. It was stated by Mr. Stockett that he had accumulated data showing 15 to 20 per cent. economy in favor of the machine. The principal advantage of machine work was its effect on the labor question.

[*Adjourned.*] WM. H. BRYAN, Secretary.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

JANUARY 25, 1887 :—Special meeting held. In the absence of the President from the city Vice-President Swasey occupied the chair.

Prof. E. W. Morley read the report of the Committee on Standard Time. Report accepted.

On motion of Professor Eisenman, the report of the Committee, that a committee from the Civil Engineers' Club be appointed to confer with the City Council, was adopted.

Mr. Rawson moved that a committee of five be appointed by the Chair to present at the first meeting in February a list of two names for each office of the Club. Motion carried.

Mr. Geo. W. Goetz read a report on Progress in Metallurgy, which was followed by a short discussion.

After a short recess, Prof. Albert A. Michelson read a report on Progress in Physics, and Prof. E. W. Morley a report on Progress in Chemistry. Both papers were briefly discussed.

The Chair announced the names of Chas. Latimer, J. F. Halloway, Hosea Paul, W. H. Searles, Prof. E. M. Morley and J. L. Gobielle, as the Committee to confer with the City Council on Standard Time.

The Chair stated that the Committee to Nominate Officers would be named later, and would be notified of their appointment by the Secretary.

[*Adjourned.*] CLARENCE M. BARBER, Rec. Secretary.

FEBRUARY 8, 1887:—Regular meeting held, President Latimer in the chair.

In the absence of the Secretary Professor Eisenman was appointed Secretary *pro tem.*

President Cady Staley, of the Case School of Applied Science, was elected an active, and Prof. Albert A. Michelson, of the same school, an honorary Member of the Club.

A letter was read from Mr. John Bogart, of the American Society of Civil Engineers, relative to the formation of a National Engineering Society.

Prof. N. B. Wood, Chairman of the Nominating Committe, presented the following nominations for Officers of the Club for the ensuing year: For President, John Whitelaw and Ambrose Swasey ; Vice-President, W. H. Searles and W. R. Warner ; Recording Secretary, C. M. Barber and James Ritchie ; Corresponding Secretary, C. O. Arey and Alex. E. Brown ; Treasurer, S. J. Baker ; Member of the Board of Managers of the Association of Engineering Societies, M. E. Rawson and M. W. Kingsley. On motion the report was adopted and the Committee discharged.

Prof. J. N. Stockwell read a paper entitled, The Use of Pairs of Circumpolar Stars for Finding Meridian Lines, and Mr. George H. Christian, of Norwalk, O., followed with a paper on The Pipeage of Natural Gas Long Distances.

As the hour was late, only the paper of Prof. Stockwell was discussed.

On motion of Mr. Wood, the Chair appointed the following gentlemen a committee to make arrangements for the annual meetings : N. B. Wood, J. F. Holloway, J. L. Gobeille, A. Mordecai, W. R. Warner, John Eisenman, E. H. Jones, John Whitelaw and S. J. Baker, and by suggestion the President was added to the Committee.

[*Adjourned.*] JNO. EISENMAN, Rec. Secy., *pro tem.*

FEBRUARY 22, 1887 :—Special meeting held at the City Civil Engineer's office.

As both President and Vice-President were absent, Mr. J. H. Sargent was elected President *pro tem.*

Mr. N. B. Wood, Chairman of the Committee on Annual Meeting, presented the report of the Committee; report was received, but not adopted. Motion by Mr. Culley to dispense with the annual banquet. Motion lost.

After much discussion, motions were carried to have the annual meeting at the club rooms on the second Tuesday evening in March, and the annual banquet at the Kennard House one week later, the price of tickets to be $1.50 each. That the President be authorized to add to the Committee such names as he thought best, and that Mr. Gobeille be appointed a Committee on Menu Cards.

On motion of Mr. Culley, the Committee on Library and Publication was requested to confer with the Case Library authorities in regard to procuring the successor to *Van Nostrand's Magazine.*

The order of the evening being the report of the Committee on Civil Engineering and Surveying, Mr. W. H. Searles read a paper on the Chapin Wrought-Iron, and on the Foundations of the Central Viaduct of Cleveland, O., and Messrs. Culley and Varney each read papers on Steel Tapes.

The thanks of the Club were tendered to the City Civil Engineer for the use of his room.

[*Adjourned.*] A. H. PORTER, Rec. Sec., *pro tem.*

MARCH 8, 1887:—Annual meeting held, President Latimer in the chair.

The reports of Recording Secretary, Treasurer, Corresponding Secretary, and Chairman of the Committee on Publications and Library were read and ordered filed, as were also the following reports: By Mr. W. H. Searles, Chairman of the Committee on Civil Engineering and Surveying; by Mr. Warner, for Professor Morley, Chairman of the Committee on Subjects pertaining to Scientific Pursuits; by Professor Eisenman, Chairman of the Committee on Architecture; by Mr. Mordecai, Chairman of the Committee on Railroad Engineering; by Professor Eisenman, Chairman of the Committee on National Public Works; by Hosea Paul, for the Committee on Standard Time; by Mr. Gobeille, Chairman of the Committee on Mechanical Engineering, and by Mr. Rawson, member of the Board of Managers of the Association of Engineering Societies.

On motion the Chair appointed Messrs. Mordecai, Thompson and Eisenman a committee to count the letter ballots received for the election of officers of the Club for the ensuing year.

Mr. Geo. S. Rider and Mr. C. F. Schweinfurth were elected active Members of the Club, and Mr. Gustavus Lindenthal was transferred from the list of active to corresponding Members.

The resignations of Messrs. E. C. Pechin and James Withycombe were received and accepted.

The Committee appointed to count the ballots reported the following persons as having been elected: John Whitelaw, President; W. R. Warner, Vice-President; C. O. Arey, Corresponding Secretary; C. M. Barber, Recording Secretary; M. E. Rawson, Member of the Board of Managers of the Association of Engineering Societies, and S. J. Baker, Treasurer.

[*Adjourned.*] C. M. BARBER, Rec. Secy.

MARCH 15, 1887:—The members and invited guests assembled at the Kennard House, and participated in the seventh annual banquet of the Club. Mr. Chas. Latimer, the retiring President, presided, and the following gentlemen responded to toasts: Messrs. Whitelaw, Chaflin, Wood, Leland, Searles, Gobielle, Sargent, Eisenman, Paul, Holloway, Warner, Varney, Walker, Dr. Biggar and Wm. M. Day.

The evening was one that will long live as a green spot in the memories of the Club. C. M. BARBER, Rec. Sec.

MARCH 22, 1887:—Special meeting held, President John Whitelaw in the chair.

Mr. J. H. Sargent read a paper on Street Pavements, Past, Present, and Future.

In the discussion which followed, Mr. J. F. Holloway read a number of letters, which were replies to inquiries in regard to pavements in other localities.

[*Adjourned.*] C. M. BARBER, Rec. Secy.

APRIL 12, 1887:—Regular meeting held, President John Whitelaw in the chair. The minutes of the last two meetings were read, and on motion of Mr. Gobeille, the minutes of March 8, 1887, were ordered corrected by striking out all pertaining to the number of votes cast in the election of officers. The minutes were then approved. The application of Mr. George E. Hartnell for membership was received and referred to the Committee on Membership.

The Secretary read the list of standing committees for the ensuing year as prepared by the President.

Publication and Library: James Ritchie, M. W. Kingsley and M. E. Rawson

Membership: G. A. Hyde, Ambrose Swasey and John Eisenman.

Civil Engineering and Surveying: Charles Latimer, W. P. Rice, J. D. Varney, W. T. Blunt and Cady Staley.

Railroad Engineering: W. H. Searles, A. Mordecai, Wm. M. Wood, H. F. Dunham and H. C. Thompson.

Mechanical Engineering: John Walker, J. L. Gobeille, N. S. Possons, J. F. Holloway and Walter Miller.

Architecture: J. N. Richardson, J. M. Blackburn, C. O. Arey, F. A. Coburn and C. F. Schweinfurth.

Subjects Pertaining to Scientific Pursuits: N. B. Wood, Geo. W. Geotz, Geo. Bartol, E. W. Morley and N. M. Anderson.

In the absence of the Chairman of the Committee on Banquet, the Secretary read the report of the Committee, which showed a deficit of eleven dollars, which on motion, the Treasurer was instructed to pay from the funds of the Club.

The remainder of the evening was spent in the discussion of street pavements.

On motion of Mr. Eisenman, the next semi-monthly meeting was dispensed with.

[*Adjourned.*] C. M. BARBER, Rec. Secy.

WESTERN SOCIETY OF ENGINEERS.

MAY 3, 1887:—The 236th meeting was held at 7:30 P. M., President Artingstall in the chair.

The minutes of the preceding meeting were read and approved.

Upon ballot Messrs. Robert Gillham, civil engineer, Kansas City, Mo., and Frank Churchill Horn, Principal Assistant Engineer, Town of Lake, Cook County, Ill., were elected Members.

Mr. Strobel, for Committee on Rooms, reported that it was considered most desirable that the present quarters be retained for the ensuing year.

The report was accepted and the Committee discharged.

It was voted that the Secretary be authorized to dispose of the carpet which has been stored since the Society moved to its present rooms.

A paper, by Mr. Samuel McElroy, on Hydraulic Motion, was read by title, and referred to Committee on Construction.

It was voted that the portrait of President Artingstall be added to the portrait gallery of the Society.

Mr. Parkhurst gave a verbal description of the bridge now being built at Omaha to replace the original structure constructed by the Union Pacific Railway Company in 1869.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

ENGINEERS' CLUB OF KANSAS CITY.

MAY 2, 1887 :—Regular meeting held in the Club Room, 19 Deardorff Building, President Knight in the chair.

The following Members were present: Wm. B. Knight, Clift Wise, H. J. Mason, A. E. Swain, S. A. Mitchell, E. B. Kay, J. A. L. Waddell, W. H. Breithaupt, A. R. Elliot, K. Allen, O. Sonne, R. C. Simons, C. E. Taylor.

The minutes of the last regular meeting, and of the last meeting of the Executive Committee were read and approved.

The following Members were declared elected :

Thos. A. Wynne, Mechanical Superintendent Metropolitan Street Ry. Co.

Wm. Norris, Chief Engineer, Chicago, Kansas City & Texas R. R.

Emerson W. Grant, Resident Engineer, Chicago, Santa Fé & California R. R.

M. K. Bowen, Assistant Engineer, Kansas City Cable Ry.

R. C. Pearsons, Resident Engineer, Kansas City Water-Works.

John F. Wallace, Resident Engineer, Sibley Bridge.

Wm. D. Jenkins, Engineer in charge, Randolph Bridge.

Amendments to By-Laws were passed, increasing initiation fees by 50 cents and annual dues by three dollars per Member.

The following names were proposed :

For Member: G. P. N. Sadler.

For Associate Members: C. G. Wade and C. A. Burton.

The paper of the evening was then read—" Work with Submarine Armor"—by G. W. Pearsons. This narrative of the writer's personal experience was illustrated by drawings and photographs.

Mr. Wm. H. Breithaupt presented a fine lithograph of the new bridge over the St. Lawrence at Lachine, containing the largest continuous girder in the country.

[*Adjourned.*] KENNETH ALLEN, Secretary

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THE PRESERVATION OF RAILWAY TIES AND TIMBER BY THE USE OF ANTISEPTICS.

BY JOSEPH P. CARD, MEMBER OF THE WESTERN SOCIETY OF ENGINEERS.

[Read April 5, 1887.]

The antiseptics that have been used up to the present time to any considerable extent in the preservation of railway ties and timber are: Corrosive sublimate, kyanizing; sulphate of copper, Boucherie; chloride of zinc, Burnettizing; and dead oil, creosoting.

Many others, however, have been tried in the past 50 or more years, and abandoned for one cause and another, which I will not attempt to explain, but will confine my remarks to those now in use.

Corrosive sublimate is the most powerful poison of them all, and its antiseptic properties are some fifty or more times greater than sulphate of copper, or chloride of zinc; that is, a solution of one part corrosive sublimate in 10,000 parts of water would, according to the best authorities, be more than an equivalent to sulphate of copper diluted one part in 400, or chloride of zinc one part in 200 of water, which is about the minimum at which they will preserve.

In treating timber with corrosive sublimate, it is generally placed in large wooden vats for one day for each inch in thickness, not counting the day it is put in or taken out, or say, ten days for an 8″ × 8″ square stick.

The handling of the timber after treatment has to be done with care, or serious consequences may follow. The solution used has generally been one part in 100 of water.

The treatment with sulphate of copper has generally been done by the Boucherie process, or in copper cylinders, on account of its corrosive properties, while the treatment with chloride of zinc is done in iron cylinders, which cost, say, ten times less than copper. All three of these salts being more or less liable to be chemically changed or washed out of the wood, and as the chloride of zinc has, under most conditions, when injected in proper quantities, answered equally as well, and being cheaper and more economically handled, has come more generally into use than either of the others. In fact, comparatively speaking, corrosive sublimate and sulphate of copper have practically gone out of use.

Chloride of zinc has served a good purpose in the preservation of railway ties in Germany, while in England the treatment has not been satisfactory; in fact, has been abandoned. Now, why this great difference in

results? The roadbeds are, as I understand it, alike (rock ballasted), consequently the drainage is the same. It must be on account of the impurities absorbed into the ties from England's moist climate, which changes gradually the chloride into a non-antiseptic, for rainfall, as a rule, will not, so far as my observations go, wash it out. It takes more than rain; in fact, it means submerging it in water; and this would hardly occur on a rock ballasted roadbed. If a tie was reasonably dry and in rock ballast, and it should rain, it would absorb moisture slowly as it rained; the flow would be inward, taking more or less of the salt with it, for any of the soluble salts mentioned will, to a certain extent, move around through the wood in whatever direction the moisture goes. When it rains, it goes inward or towards the centre; when the moisture evaporates, to the point of evaporation. I have had this tested by analysis to my entire satisfaction.

If ties were submerged, or partially so, in water for any considerable time, the chloride, being of greater specific gravity than water, the tendency would be to go out of the ties rather than inward, or to equalize with the water surrounding them. Again, if the ties were in sand (like the Rock Island ties, which I will mention later on) the result would be, when your sand was moist or wet they would absorb moisture where they come in contact with it, and as it gradually moved to the point of evaporation, which would be the top or exposed portion of the ties, it would carry with it more or less of the chloride. This constant, or at certain seasons of the year long-continued evaporation, weakens, in my opinion, the strength of the chloride at point of contact with the ground or moisture below the minimum of its preserving properties, and in the case of the Rock Island ties, which were in clean sand, they gradually decayed where they came in contact with the ground, but remained sound on top as a general thing.

Again, should there be impurities in the ground or water surrounding the ties, or in rainfall, that would combine with the chloride or any salt and transform it into a non-antiseptic, as oxide of zinc, the change would be more or less rapid, and it is in this way that I account for the bad results with chloride of zinc in England, and from rainfall, if ties are on rock ballast.

I know of Burnettized gum wood ties that were placed in cinder and slack coal ballast in 1880 (the cinders and slack came from a coal mine dump that had been burned over), that were worthless in twelve months after being placed in the track, while ties treated at same time that were placed in sand, are sound to-day, or were, when I examined them last year.

I don't mean to say that all cinders and slack will produce this result, but these did; neither do I wish to convey the idea that the changes mentioned heretofore occur in a day. Some of them may in a month, or as in the case of the Rock Island ties, their average life was over fifteen years.

There is a section, or some twenty miles, of the Union Pacific Railroad where the ties have been preserved since the road was first built, by the soil in which they lie.

With reference to creosoting, or the use of dead oil in wood preserving

If you inject a sufficient quantity of oil (of proper quality after steaming and vacuum) into ties, or timber, they will remain sound so long as the oil remains undisturbed, if it enters the wood but one half-inch, or even less, on the sides of say, a $10'' \times 10''$ stick of timber, notwithstanding the oil remains practically where it is placed at time of treatment, and does not diffuse through the wood, like chloride of zinc, and for the following reasons :

Dead oil contains carbolic and other acids, which are more or less soluble in water, and enough of these acids combine with the moisture in the wood at time of treatment to destroy the fermentable or other matter then in the wood, that tends to decay, and any impurities or germs of decay thereafter coming from the outside will have to pass through the dead oil, and in doing so, are destroyed or rendered inert.

The trouble with creosoting is to get the dead oil where you want it (it will stay where you put it) and the cost. The trouble with a mineral salt, or chloride of zinc, is to keep it where you put it, or where it places itself shortly after treatment, if the work on your part is properly done.

Having given you my experience, as well as ideas as to the benefits to be expected from the proper use of mineral salts and dead oil when used by themselves, I will now submit for your consideration and discussion before this Society, the process known as the "zinc creosote" process, which consists in the use of both dead oil and chloride of zinc in combination, for the preservation of railway ties and timber from decay, as well as protection against the attacks of the teredo where timber is placed in the sea.

For railway ties, bridge timber, and the like, or where timber is subjected to no considerable moisture, as when placed on or in the ground, the process is as follows :

After preparing the timber in the usual way by steaming and vacuum, the dead oil is run into the cylinder, and such quantity as may be desired is forced into the wood.

For railway ties or timber I would recommend, say one-half gallon to the cubic foot, or 1½ gallons to the tie. A less amount may be found to answer. After the timber has been treated with oil, the oil is removed and cylinder charged with chloride of zinc, when by pressure it can be made to enter the wood, pass through and beyond the oil, and impregnate by diffusion that portion of the wood that the oil will not penetrate, especially where timber is not well seasoned or dense like oak. The aim of this process is to get the benefit of the dead oil treatment where ties or timber come in contact with the ground or moisture, with one-half or less oil, besides having those portions of the wood not penetrated by the oil impregnated with the zinc chloride. The zinc chloride, surrounded as it is by oil, should be protected for a long time in railway ties or bridge timber against moisture. I find that less than one-half the quantity of oil used in ordinary creosoting can be distributed by this process through every portion of the wood penetrated by the greater quantity injected in the usual way.

Creosoting, as practiced abroad, unless a much larger quantity of oil is used on railway ties than is used in England (6 to 10 pounds to the cubic

foot), is of little value in my opinion, unless a chair is used under the rail to take the wear, for the following reasons:

Where dense woods are used, in fact it is the case with many of those considered porous, the heart wood will take the oil but skin deep, consequently the oil is in time worn off by the rail, decay commences and at the worst possible place, the spike becomes loose and the tie valueless.

This is probably the reason there were so few American creosoted ties exhibited at the Exhibition of Railway Appliances in 1883, and the few there were had been treated to at least two gallons of oil to the cubic foot. If I am not correct I would ask what has become of the thousands that have been treated in the past thirty years in this country, where we use no chair?

I have here one of a lot of ties treated by a Mr. Pelton some years since for the Chicago, Rock Island & Pacific Railway Company, and placed in their tracks near Englewood. It was taken up in May, 1883, for exhibit at Chicago Exposition of that year. These ties were treated by what is known as the Seely process, in 1872, and notwithstanding they contained but little oil (less than four pounds to the cubic foot), were sound so far as examined by me where they came in contact with the ground, but commenced to decay (so I was told) under the rail as soon as the oil wore off, and not before.

If a sufficient quantity of oil is used to impregnate the ties to a considerable depth at point of contact with the rail (which means for oil, say fifty cents or six gallons to the tie, and this applies only to soft woods and not to oak), a good result would be obtained; otherwise, a chair must be used.

If you will show me one tie that has served a good purpose, I will convince you it was treated to at least six gallons of oil, or a chair had been used. Not but what a much less quantity would preserve it from decay if placed in the ground as a post and undisturbed, but should you remove the oil at the ground line, it matters not to what extent, so the untreated timber is exposed, you will find your creosoting of little value, and this is the experience of all.

Mr. J. W. Putnam, of New Orleans, in a letter of June 20, 1885, to the Chairman of the Committee on Preservation of Timber of the American Society of Civil Engineers (I presume many of you know him), says: "With reference to creosoting, wherever the coating is broken and the air with its dust allowed to come in contact with the untreated wood, decay follows and extends in each direction from the opening," and he is but one of the many who make this or similar statements.

The Burnettized ties on the Chicago, Rock Island & Pacific Railway, near Englewood, and so far as I have examined those from other roads (where work was well done) were sound under the rail, but decayed where they came in contact with the ground.

Mr. Alexander, in his report of March 23d, 1882, to Mr. Hugh Riddle, then president of the Rock Island road, says: "I made a careful examination of the Burnettized hemlock ties we laid in main track just west of Englewood in November, 1866, last summer, and found at least seventy-five per cent. of them still in the track, and, in my opinion, in such a state of preservation that they will be serviceable for two or three

years longer. Some five or six of these ties were taken out of track and found to be sound and solid in the centre and only decayed to the depth of one-half to three-quarters of an inch on the surface and sides. The rail has not worn into these hemlock ties to any greater extent than would have occurred with oak, and they hold a spike fully as well as the oak tie. The pine and cedar ties that were Burnettized at the same time have worn out in the fifteen years' service, and have disappeared. The tamarack have held out about the same as the hemlock." Continuing he says: "My experience is that untreated hemlock ties decay first in the centre or heart, when the spike becomes loose and the tie crumbles; but these treated ties are sound in the centre, which shows that where the chloride of zinc is not washed out, the wood is in a perfect state of preservation."

I saw these ties a short time after they were taken up, and examined those remaining in the track in June, 1883 (they had then been down over seventeen years), and found them to be sound under the rail with hardly an exception. I also had the sound wood from several of these ties analyzed, and found them to contain from .05 to .14 of one per cent. of chloride of zinc to weight of the wood when dry.

Again, in the same report (March 23, 1882), Mr. Alexander says: "In 1872 we laid in second track east of Washington Heights about 5,000 hemlock ties that were subjected to the creosoting process. These ties I do not believe were thoroughly treated. They seemed to be tolerably sound at the bottom, but are badly decayed on the surface, and the rail wears into them to a much greater extent than it does into those that were treated with chloride of zinc. There is probably not more than from 30 to 50 per cent. of these creosoted ties now in track, and these will, no doubt, all be taken out this summer."

I examined these ties, or what there was left of them, in June, 1883, finding few then in the track, but was fortunate, however, in finding several hundred that had just been taken up and piled along the track. Nearly all of them showed results of which the creosoted tie exhibited here, which was one of them, is a fair sample.

If I am correct, what can be expected of creosoted ties with but 6 to 10 pounds of oil to the cubic foot if used as they are in this country in direct contact with the rail, and what must we do to get best results in the preservation of our ties. Use a chair as in England, or open porous woods and inject 50 to 75 cents worth of oil into each tie, or will a double treatment first with dead oil and then with chloride of zinc answer the purpose; the dead oil to preserve the outer or exposed parts which it will do, and the zinc chloride the central portions, which the oil does not penetrate to any considerable extent in our most desirable woods. So far as my observations and experiments go, I am satisfied that time will demonstrate that dead oil and chloride of zinc injected into ties and timber as proposed, will give the best results for money invested, and where dense woods are used, especially for ties, the best result, without regard to cost.

You may say that the old way of creosoting closed the pores, thereby keeping out moisture. Dead oil will not keep moisture in or out of wood like paint, tar or pitch for any considerable time. Moisture will

not enter a creosoted tie above the surface of the water surrounding it, or without pressure; neither will it enter except under same conditions where the fibre is oiled. This being the ease, your ties, under most conditions, will remain dry and the zinc chloride should be protected.

Again, you seldom see decay in wood the fibre of which has once been covered with dead oil, to such an extent as to be seen by the eye. The zinc creosote process will, as I said before, distribute one-half or less oil in every part penetrated by the greater quantity when injected in the old way, and in such quantities as can be readily seen.

You may say, would it not be better to first inject the chloride and then the dead oil? If the treatment were reversed, you would have to remove a portion of the moisture before the oil could be injected. Wood, being one of our best non-conductors of heat, the process would be tedious, and timber or ties would be more or less injured by the long continued application of the heat required to evaporate sufficient moisture. In fact, the only cheap and practical way would be to air, dry, or stack the timber until sufficient moisture has evaporated, and then apply the oil. I do not believe there would be anything gained by so doing, and it would add greatly to the cost.

With reference to the treatment of piling with dead oil as protection against the teredo. The old way is to inject all the oil the timber will take (which depends on the piles being more or less dry and the kind of wood operated on) from one to three gallons to the cubic foot. The object of the zinc creosote process is to economize in the quantity of oil used and nothing more, and consists in first injecting, say two-thirds (one-half may be found to answer) of the quantity used in the old way, and then by substituting some other fluid for the oil, as chloride of zinc, air or water by pressure, compress or force the two-thirds previously injected solidly to the centre, which leaves the two ends, the one in the mud or ground, the other above water, with their fibres virtually painted with the dead oil, while the centre of the pile or that portion in the water is as well treated and contains as much oil as would be the case if the whole quantity used had been oil. I would prefer an antiseptic for the second injection, as it would help to preserve that portion above water from decay.

Thanking you, gentlemen, for your kind attention, I would, in concluding, say that we have at our works, Fifteenth and Clark streets, a small experimental cylinder which is at the service of this Society, or any of its members, should they desire at any time to make experiments in this line.

ON THE USE OF PAIRS OF CIRCUMPOLAR STARS FOR FINDING THE TRUE MERIDIAN.

By Prof. John N. Stockwell, Member of the Civil Engineers' Club of Cleveland.

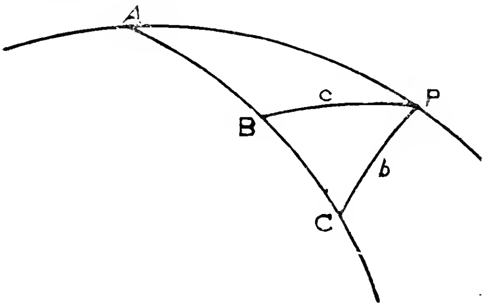
[Read February 8, 1887.]

One of the most convenient methods of finding the true meridian, when the latitude of the place is known, consists in observing the direction of the vertical which a pair of circumpolar stars simultaneously transit. The consideration of the spherical triangle of which the celes-

tial pole and the places of the two stars are the three vertices, enables us to deduce two methods of finding the direction of the meridian. If we conceive the arc of the great circle which joins the two stars to be continued indefinitely in opposite directions, it is evident that such great circle will sweep over all points of the earth's surface which are more distant from the pole than such great circle. Consequently the great circle connecting the two stars becomes a vertical circle twice a day to all places on the surface of the earth whose polar distance is greater than the polar distance of the circle passing through the stars. The angle which such vertical circle makes with the meridian is called its azimuth, and evidently depends on the latitude of the place and the polar distances of the stars.

In the spherical triangle already mentioned, we know the two sides, which are the polar distances of the two stars, and also the included angle, which is the difference of their right ascensions. We may therefore easily find the other two angles of the triangle, and also the third side; but the third side will not be needed.

Now, let us designate the place of the zenith by A, and the places of the stars by B and C, and the place of the pole by P. In the triangle



PBC we may suppose that all the parts are known, and whenever A, B, C, are in the same great circle we shall have $\cos\varphi \sin A = \sin B \sin c = \sin C \sin b$, in which φ denotes the latitude of the place. Now the second members of this equation depend only on the places of the stars; and we may select such stars as will render the second members nearly constant during a long series of years. Then in order to find the azimuth A of this great circle, we have only to divide by the *cosine* of the latitude and we have the *sine* of the angle A, which is the common azimuth of the two stars.

The choice of stars to be observed is a matter of some consequence in this method of determining a meridian line. They should be bright stars, so as to be easily recognized, and should be at least ten degrees apart, so that the errors of observation would have as little influence as possible on the position of the vertical circle passing through them. If they are at nearly equal distances from the pole they will be in the vertical of any place at nearly equal intervals of time before and after passing the meridian; and if they are pretty near the pole they will serve the purpose of finding the meridian throughout the greater part of the hemisphere.

The two stars which seem to be most favorably situated for the purpose are *Merak* and *Alioth*. *Merak* is the one of the Pointers most distant from the pole; and *Alioth* is the third star from the end of the tail-both being in the constellation of the Great Bear. The polar distances of these stars are 32 degrees 49 minutes and 33 degrees 14 minutes respectively; and the angle at the pole between them is 28 degrees 40 minutes. In the year 1850 the angle $B=79$ degrees 22 minutes 53 seconds, in 1890 $B = 79$ degrees 30 minutes 5 seconds, and in 1930 $B = 79$ degrees 37

minutes 45 seconds; and the values of c for the same dates are 32 degrees 48 minutes 53 seconds, 33 degrees 1 minute 41 seconds, and 33 degrees 14 minutes 27 seconds respectively.

We may, therefore, easily compute a table of the values of the logarithms of cos φ sin A, extending over a period of at least two hundred years from 1850, with sufficient accuracy for all the purposes of the land surveyor, by the following formula:

$$\log \cos \varphi \sin A = 9.72644 + 0.00006625 . t;$$

in which t denotes the number of years after 1850. We may, therefore, write the following table of log cos φ sin A:

Date.	log cos φ sin A.	Date.	log cos φ sin A.
1850	9.72644	1901	9.72983
1860	9.72710	1902	9.72990
1870	9.72776	1903	9,72996
1880	9.72842	1904	9.73003
1885	9.72876	1905	9.73010
1886	9.72883	1906	9.73017
1887	9.72890	1907	9.73023
1888	9.72896	1908	9.73030
1889	9.72903	1909	9.73037
1890	9.72910	1910	9.73043
1891	9.72917	1911	9.73049
1892	9.72924	1912	9.73056
1893	9.72930	1913	9.73063
1894	9.72937	1914	9.73070
1895	9.72944	1915	9.73076
1896	9.72950	1916	9.73083
1897	9.72957	1930	9.73175
1898	9.72964	1970	9.73440
1899	9.72970	2010	9.73705
1900	9.72976	2050	9.73970

By simply subtracting the *log cosine* of the given latitude from the numbers in this table, we get the *log sine* of the azimuth at the corresponding date. Thus for the year 1888. in 41 degrees 30 minutes we find A = 45 degrees 40 minutes 10 seconds, which is the common azimuth of the two stars when in a vertical circle passing through that latitude, whether east or west of the meridian. After having found the direction of this vertical circle on the ground, we only need to lay off another line at an angle of 45 degrees 40 minutes 10 seconds with it to the northward, and we have the position of the true meridian passing through the given place.

The second method of finding the meridian from the same observations depends on the hour angle $A\,P\,B$. This method seems to me far less convenient than the one already explained; and for the following reasons: 1. The determination of the hour-angle of the star from the data of the problem is very much more laborious than the determination of the azimuth angle. 2. After the hour-angle is computed it is necessary to wait for the star to come to the meridian after the observations are made, and sight the star when in the meridian, and we get at once its true direction. By the first method we turn off the proper azimuth ourselves at the time of making the observations; in the second method we wait for the star to turn it off. Now, unless the star should happen to be very near the meridian at the time of the observation, it would be very inconvenient to employ this method at all, not only on account of the

inconvenience of waiting a long time, but also from the danger of clouds obscuring the star at the moment of meridian passage.

In the case of the two stars already considered, in the latitude of 40 degrees, the star *Merak* comes to the meridian 3 hours after being in the same vertical circle with *Alioth*; so that while by the first method we could turn off the true meridian in three minutes of time, it would require three hours by the second method. These two stars are therefore not well adapted for determining the place of the meridian by the second method.

Writers on surveying have selected the *Pole Star* and *Alioth* as the two stars most proper for finding the true meridian; but on account of the extremely loose directions they have laid down for surveyors in the application of the method, I have thought it might be of some interest to bring the subject before the Club.

Thus Gillespie says that in 17 minutes after *Polaris* and *Alioth* are in the same vertical circle, *Polaris* will be in the meridian, and may be sighted after that interval with perfect accuracy. Schuyler, in a work published some twenty years later than Gillespie's, also says 17 minutes; while Wentworth and De Volson Wood, in some quite recent works, say that the interval should be 22 minutes. Davies says that if you sight *Polaris* while in the same vertical with *Alioth* you have the meridian very nearly; and Mr. W. S. Chaplin, in the Proceedings of the Civil Engineer Club of Philadelphia for May, 1884, gives the interval as 25 minutes 36 seconds for the latitude of 40 degrees.

Gillespie's work was published about the year 1855, and we may properly suppose that it was designed for the use of surveyors in the latitudes of the United States, which are nearly all included within the parallels of 30 degrees and 50 degrees. Now we have seen that the latitude of the place enters as an element into the determination of meridian lines; and if we inquire at what place on the earth's surface *Polaris* was in the meridian exactly 17 minutes after being in the same vertical with *Alioth*, we shall find the parallel to be 46 degrees 4 minutes south latitude, in the year 1850. In the year 1854 the required latitude was 55 degrees north; in 1858 it was 66 degrees 4 minutes north; in 1866 it was 28 degrees 45 minutes; in 1886 it was 86 degrees 30 minutes; while in 1986 it will be 89 degrees north latitude. We thus see that *Polaris* has never passed the meridian in exactly 17 minutes after being in the same vertical circle with *Alioth*, at any point of the United States, since the publication of Gillespie's work, although it did a short time before. None of the writers above mentioned give the date or latitude at which the rule is supposed to be true, except Prof. De Volson Wood, and his calculation is made for the latitude of Hoboken (40 degrees 44 minutes), and for the beginning of the year 1884. But in his calculation he unfortunately took the right ascension of *Alioth* one degree too great; so that he should have found the interval of time to be 25 minutes 49 seconds, instead of 22 minutes 1 second, thus making his result 3 minutes 48 seconds in error.

In order, therefore, to make this second method convenient and accurate, it would be necessary to prepare a table of double entry, with the latitude of the place for one argument, and the time or year for the other;

but even with this degree of elaboration it would be far less convenient for use than the first method; because the interval between the observation and meridian passage is constantly becoming greater. Thus in latitude of 40 degrees, in 1850, it was 16 minutes 35 seconds; in 1870 it was 21 minutes 42 seconds; in 1890, it will be 27 minutes 46 seconds; in 1910 it will be 35 minutes 2 seconds; in 1930 it will be 43 minutes 49 seconds; while in the year 2100 it will amount to 4 hours 50 minutes 34 seconds. We thus see that the interval is not only rapidly increasing, but that it increases at a rapidly increasing rate. In the year 1787, just one hundred years ago, the right ascensions of *Polaris* and *Alioth* differed by just 12 hours, and, consequently, they passed the meridian and vertical circles at the same time in all latitudes.

In the motion of the pole of the equator around the pole of the ecliptic it crosses the great circle which joins the two stars *Polaris* and *Alioth* in two points. About the year 1787 the celestial pole was directly between these two stars, and a little less than *two degrees* distant from *Polaris*, and about 1,700 years before, it was also directly between them at a distance of a little more than eleven degrees from *Polaris*. The pole of the heavens has therefore been in peculiar relations to these two stars for more than *two thousand years*; but this close relationship will soon cease to be recognized, and will altogether disappear during an interval of more than twenty-three thousand years, when the conditions of the past two thousand years will be renewed.

DISCUSSION OF PROFESSOR STOCKWELL'S PAPER.

Mr. Varney: Does the change in the position of the stars affect the use of them for this purpose?

Prof. Stockwell: You can consider that the stars are absolutely fixed in position with reference to the motion of the earth. I found during a period of 40 years that the absolute distance between two stars changed only one second of arc. We may consider these particular stars as absolutely fixed. The changes that take place are due to the motion of the celestial pole in space. The precession of the equinoxes causes the celestial pole to describe a complete circle in about 25,000 years. *Alpha Lyra*, the brightest star in the northern hemisphere, will be the pole star in 13,000 years. Shows diagram. The places of most stars can be readily calculated, but for stars near the pole the calculation is very complicated unless you have special tables and formulas. I prepared a set of tables for this purpose about 15 years ago, which were published by the Smithsonian Institute. There is no other work of the kind published so far as I know. I do not mention this to advertise my work, but because the information contained in it may be useful. I carried the computation to cover a period of 8,000 years before the present time and 8,000 years after.

Mr. W. H. Searles: Will Prof. Stockwell put on the board a chart of the heavens including the dipper, a view of the dipper and the two stars with the vertical passing through them.

Prof. Stockwell shows diagram.

Mr. Searles: Then two observations could be taken on the same night about six hours apart.

Prof. Stockwell: Yes, sir.

Mr. Varney: I understand you that the observation is to be made when the plumb line will cover these two stars.

Prof. Stockwell: Yes, sir; you have the sine of the horizontal angle between the meridian and the vertical.

A Member: You say that we have the records showing the position of he north star in the early ages.

Prof. Stockwell: We have the records from some 2,000 years ago. The star, which is now the pole star, was then 12 degrees from the pole.

Prof. Eisenman: You remarked that the azimuth was the same on both sides of the meridian. Further, did I understand you to say that the method was more accurate than any other? If so, why?

Prof. Stockwell: The azimuth is the same in amount on both sides of the meridian; but it, of course, has different signs. I do not know that this method is any better than other methods. The only advantage is that you can fix it with a less accurate instrument. You could fix it with an ordinary compass, but you could not observe the elongation of the star. My remarks are in reference to the method given in the books.

Prof. Eisenman: My object in asking was to ascertain if this was the most practical method of getting the true meridian.

Prof. Stockwell: If you have the accurate time you can get the true meridian with the theodolite in a much shorter time.

Mr. Searles: I would suggest that the two methods are easily combined Whenever two stars are on the vertical one has recently passed its elongation, the other is approaching its elongation. We would have, then, three observations on the same evening by which to verify our work.

Prof. Eisenman: By observing *Polaris* (any other common polar star would do) at elongation the true meridian may be found very readily. You will find the method very much more accurate. It has been adopted even in more refined work of the government. For ordinary purposes, when observations within one minute are required in taking the star's elongation, all you have to do is to watch it for 20 to 25 minutes as it appears to travel in a straight line along the vertical. No particular referenee need be made regarding the time of elongation-azimuth of the star, for that date may be obtained with the aid of a nautical almanac.

Prof. Stockwell: Skillful astronomers can use them, but ordinary surveyers who are not acquainted with the nautical almanacs would have trouble. I wish to say, in conclusion, with regard to Gillespie's work, that Prof. Staley has just issued a revised edition; but as I have not seen it, I am unable to say how he has treated the question.

Mr. Latimer: Do I understand that Mr. Wood's method is three minutes and forty seconds wrong.

Prof. Stockwell: Yes, sir; the place of the star *Alioth* was at least four minutes of time in error, which causes the hour angle of the star to vary by the amount mentioned. I understand that surveyors still adhere to that method.

Mr. Varney: I doubt whether any one has been more interested in the paper than I have, but I cannot concede that this method could be useful

for surveyors. We do not go to the stars to inquire the way over the earth. We now take other methods of fixing meridian lines.

Prof. Eisenman: I beg to differ with the gentleman. We must go to the stars to fix these meridian or base lines. The pole may change its position with reference to the stars, but not a terrestrial line in reference to the pole. Hence a line when once definitely fixed by astronomical observation is regarded as fixed until glaring errors are discovered. I do not find any use myself for this last method. I studied it in Gillespie and found it in Davies, but in my own teaching and practice have discarded it as obsolete.

Mr. Varney: I want to confine my observations to land surveying, to the fixing of property lines for individuals.

Mr. Baker: How would you run north and south lines in new countries without the use of the meridian or the needle?

Mr. Varney: What I protest against is the idea that when the line is run north and south you have something fixed. The supposition is that you have something to start from on the earth, one monument at least, now place one at the other end of the line and you do not need to refer to the stars again.

Mr. Searles: The discussion hardly does justice to the paper. We are much indebted to Prof. Stockwell for introducing to us this method. Whether the use of pairs of circumpolar stars is superior to the method of elongation for finding meridian lines is a question which is yet to be determined.

Prof. Stockwell: I did not write the paper with the intention of recommending the method, but as it had been given in the books in a very faulty manner, I wished to point out the errors. I think that there are better methods of finding meridian lines.

Mr. Force: Is the method of elongation used by the Government surveyors?

Prof. Eisenman: More observations are taken in that way than by any other method. The higher the order of work the more refined the observations.

BOSTON SOCIETY OF CIVIL ENGINEERS—REPORT OF COMMITTEE ON WEIGHTS AND MEASURES.

[Presented March 16, 1887.]

To the Boston Society of Civil Engineers:

Your Committee on Weights and Measures respectfully presents the following report:

Standard Time.

The adoption of standard time, which took place November 18, 1883, has been followed by the introduction of the twenty-four hour system of notation.

The special committee on Standard Time of the American Society of Civil Engineers, at the annual meeting of that society in January last, submitted a detailed report in reference to the general adoption of the twenty-four hour notation on the railways of America. The following

extracts are made from that report to indicate the extent and success of this movement:

"It was publicly announced that the Canadian Pacific Railway Company had decided to test the advantages claimed for the twenty-four hour system of notation by an actual trial on a portion of their transcontinental line.

"Accordingly, at mid-summer last year, when the through line was opened for public traffic, the time-tables were arranged for the change of notation between Port Arthur, on Lake Superior, and Vancouver, on the Pacific Coast. This portion of the railway comprises the Western and Pacific Divisions, 1,913 miles of main line, which together with branches and connections using the new system, embrace in all over 2,600 miles of railway. It extends across the 'Central,' the 'Mountain,' and the 'Pacific' standard time zones. * * *

"The Vice-President, Mr. Van Horne, has placed at the service of the committee a large number of letters received on the subject from the principal officers on the Western Division, conductors and agents, mayors of cities, the Lieutenant-Governor and the Premier of Manitoba and others. These letters, furnishing information as to the results of the experiment during six months which have intervened, * * * afford overwhelming testimony on two points, viz.:

"1st. The great advantage of the twenty-four hour system in operating railways.

"2d. The readiness with which business men and the general public accept the change. * * *

"The experiment of the last six months has determined the Canadian Pacific Railway Company to adopt the twenty-four hour system *permanently*, on every division, every branch and every connecting line under its control. The next time tables issued will extend the use of the new notation eastward to Toronto and to Ottawa, the capital of the Dominion. In another year, when the extensions of the Pacific Railway will be completed, it is expected that the twenty-four system will be put in force within the limits of every province of Canada from Nova Scotia on the Atlantic to British Columbia on the Pacific."

The American Society of Civil Engineers then adopted the following resolutions:

"1st. That the Report of the Special Committee on Standard Time, now submitted, be accepted, and the Committee continued.

"2d. That a copy of the report and accompanying letters be transmitted to the secretaries of the several railway time conventions, with the request that they take into consideration the propriety and expediency of adopting the twenty-four hour system on all the railways in North America at the next change of time-tables, and that the Board of Direction of this Society be authorized, if they consider it expedient, to send copies to the leading railway officials of the country.

"3d. That the special committee be instructed and authorized, with the approval of the Board of Direction, to take such further action as may be deemed expedient to advance this important movement.

"4th. It is the sense of this society that it is desirable, for the purpose of familiarizing the public with the change involved in the introduction

of the twenty-four hour system, that the mayors and corporations of the principal cities in the United States, Canada and Mexico have the dials of public clocks adapted to the new notation; also that it is desirable that the post-office departments of the United States, Canada and Mexico introduce the twenty-four hour system of notation in the post-offices of the country and in such publications on postal affairs as refer to the hours of the day."

During the month of February a bill was introduced in the Legislature of the State of New York authorizing the use of this new notation as a legal standard. The bill contains the following sections:

"Section 1.—The hours of the day, from midnight to midnight, may be designated by consecutive numbers from zero to twenty-four, and the hour of midnight may be designated either as twenty-four o'clock of the day then ending, or as zero o'clock of the day then beginning.

"Section 2.—This act shall take effect immediately."

Standard Sizes for Wrought-Iron Pipes and Pipe Threads.

At the sixth annual meeting of the American Society of Mechanical Engineers held in Boston in November, 1885, a committee was appointed "to confer with the manufacturers of pipe, pipe dies, and pipe-fittings, with a view of bringing about a uniformity in the sizes of pipe and pipe-threads, and of maintaining it by the use of gauges which shall definitely represent standard sizes."

At a meeting held at Hartford in February, 1886, it was agreed that:

"The opinion of this committee is that the Briggs standard, which nearly all, if not all, of the pipe manufacturers once adopted, is the proper standard to be adhered to, and that it only requires definite co-operation on the part of pipe manufacturers with the committee in order to bring their product strictly to that standard, and to adopt means of strictly adhering to it within practical limits."

The matter was brought before the various manufacturers of pipe and fittings in this country, who responded cordially. After correspondence and several conferences the manufacturers of wrought-iron pipe and boiler tubes in the United States, at a meeting held at Pittsburgh in October, 1886, resolved: "That the wrought-iron pipe manufacturers of the United States hereby adopt the Briggs standard of gauges, and that where any manufacturer has, from any cause, got away from that standard, he be requested to get such corrections made as soon as possible, so as to conform to the Briggs standard."

Subsequently the Manufacturers' Association of Brass and Iron, Steam, Gas and Water Work passed resolutions indorsing the action of the Wrought-Iron Pipe Manufacturers, and affirming "That as manufacturers of brass and iron, steam, gas and water work we will act in conformity with the resolution adopted by them."

A description of the Briggs standard may be found in a paper by the late Robert Briggs, C. E., on "American Practice in Warming Buildings by Steam," in the Minutes of Proceedings of the Institution of Civil Engineers (London), Vol. LXXI., p. 95; also in a reprint of the same in Van Nostrand's Science Series, No. 68.

Persons not having access to the Transactions of the American Society of Mechanical Engineers may find the report of the committee and a description of the Briggs standard in the *Sanitary Engineer and Construction Record* of February 26, 1887.

The Metric System.

Although the introduction of the metric system into this country has not made marked progress during the past year, that system is gradually becoming more familiar to our people by its increasing use in popular literature, in scientific periodicals, in the daily papers, and in school books. Its value as a means for the exact expression of quantity has long been recognized, and its use for scientific purposes is becoming general.

Col. Henry Flad, in his address as President of the American Society of Civil Engineers, at the annual convention in July, 1886, said : "The introduction of the metric system is also progressing, though not quite so rapidly as might have been expected from the progressive spirit of our nation. It seems strange that in this age of rapid interchange of goods and thoughts between civilized nations, such an obstacle as the use of different measures in different parts of the globe should be allowed to exist. Nobody can doubt that this obstacle will be removed before long, and the only question can be, what system should be adopted.

"There are now 242 millions of people using the metric system, and the weight of numbers is probably already on the side of that system. This may be balanced, or even outweighed, by the industrial prominence of the nations which use the English standard ; but the selection should clearly not be made either on the basis of the greater number now using a particular system, nor on the cost of the change in money, or in temporary inconvenience, but it should be made on the intrinsic merits of the system. And there can be no doubt that the metric system fulfills almost every condition of a perfect system of measurement, and could hardly be improved. * * * Our manufacturers may be willing to agree to the change when they consider that many countries showing rapid progress, such as Brazil, Mexico, and the Republics of South America, have adopted the metric system, and that this gives to France and Germany a great advantage over the United States in selling to these countries their manufactures."

Public opinion in the West appears to be more strongly in favor of the complete introduction of the metric system than it is in the East. Among the evidences of this, may be mentioned the recent action of the Western Association of Architects.

This association appointed, in 1885, a committee to consider and report upon the advisability of changing the subdivision of the standard foot measure from duodecimal to decimal subdivisions. This committee reported to the association in November, 1886, that a change to decimal subdivisions was desirable, and that among the benefits arising from such a change could be mentioned :

"1. Greater ease of operation in written calculations.

"2. Greater certainty and rapidity in mental operation with numbers of measure.

"3. Decreased liability to error in figuring drawings or in indicating any given dimension. said errors often arising from a mental confusion, caused by computing numbers decimally and duodecimally in the same operation.

"4. A general saving of time and anxiety ensuing from the abandonment of a slow and complex method of work for one simple and rapid."

The Committee recommended: "That the Western Association of Architects appoint a committee of three or more, whose duty it shall be during the ensuing year to confer personally or by correspondence with representatives of the American Institute of Architects, the several civil and mechanical engineers' societies and the leading interested manufacturers of the country, to seek with them for a common line of action, and to ascertain from many sources if this reform be practicable." They further recommended "That following such appointment an official notice of such action by this association be forwarded to the societies and others above named, asking for the appointment of similar committees on their part, or for such other consideration of the subject as to them may seem wise and proper."

In the discussion that followed, it was urged that to divide the foot into ten equal parts would be of comparatively little advantage, and would be quite difficult to introduce; that if a change be made, it should be to the metric system, which embraces not only measures of length, but also measures of capacity and weight. The President, in his remarks, said: "I think it would be injudicious if we, as architects, were to propose the adoption of merely a little trifling reform, referring only immediately to the one unit of measure employed by ourselves in our work If we really desire the decimal system, we should unite with other professions who are endeavoring to secure the adoption of the metric systems and while there is now no motion before the house with reference to this matter, as there is nothing but the consideration of the report of the committee on using the decimal notation of the foot, it might be well to suggest that the sense of the association be taken with reference to it; attitude as regards a wider range of action; that is, as regards the adoption of the metric system as a whole; and I should be very glad to hear a little wider expression of opinion on that subject."

Afterward, the following resolutions were adopted:

"*Resolved*, That the report of the Committee on the Decimal Division of the Foot be received and placed on file.

"*Resolved*, That this association recommend the adoption of the metric system of weights and measures, and that the President appoint a committee whose duty it shall be to correspond with other organizations interested in this subject and, in connection with them, petition Congress to pass a law making the use of the metric system compulsory after a reasonable period."

Interest in the metric system continues to be shown by civil engineers by placing metric scales on plans—a practice that is increasing; by the publication of metric quantities in reports, instead of converting them into British units; and by the use of metric measures in computations based upon metric constants. The use of the meter is being extended to vertical measurements in the Coast and Geodetic Survey.

The use of the metric system in foreign countries is increasing. A brief statement of the history of its introduction into the Argentine Confederation is interesting at the present time.

The law of April 10, 1863, adopted the metric system, directing instruction in it and the preparation of conversion tables, and proposed its obligatory use when it should appear expedient.

The decree of May 17, 1872, ordered it to be used in the business of the Custom-house from January 1, 1873, as a method of bringing it into general use.

The law of January 13, 1877, makes its use obligatory in all contracts and in all commercial transactions, after the *first of January*, 1887, and prohibits the use of other weights and measures than those of the metric system after that date.

Respectfully submitted,

CHARLES H. SWAN,
CHARLES W. FOLSOM,
CHARLES W. KETTELL.

BOSTON, March 15, 1887.

DISCUSSION OF REPORT OF COMMITTEE ON WEIGHTS AND MEASURES.

MR. FRED. BROOKS: The action which has been mentioned of the Western Association of Architects with reference to petitioning Congress, naturally leads to a consideration of the subject of legislation. Legislation always accompanies changes in people's weights and measures, and in this country plainly it must do so; for with us it is simply the formal expression of the popular will through our representatives, or mouthpieces. It is our way of combining individual wishes into concerted action; and as reform in weights and measures requires all citizens to act together, it is only through our Congressional representatives that it can be conducted intelligently. This is recognized in the provision of the Constitution that "the Congress shall have power to" "fix the standard of weights and measures." Congressional legislation was always contemplated by this Society's committee on the metric system; and a special committee of the American Society of Civil Engineers reporting, May 6, 1874, on some memorials to Congress in behalf of the metric system, said: "A series of legal enactments, carefully considered, cautiously introduced, and steadily pursued, is considered the proper, the wisest, and the necessary course to be pursued in the endeavor to attain these great benefits." To facilitate the conduct of reform in weights and measures, the National House of Representatives more than twenty years ago established a Standing Committee on Coinage, Weights and Measures, which is now one of its principal committees, and has a large membership. This committee has made two elaborate reports, one in 1866 and one in 1879, both in favor of the ultimate adoption of the metric system, although the membership was completely changed and the political complexion reversed during the interval between them. It is through the instrumentality of this committee that our people have to bring about reform in weights and measures; we must make it the nucleus of official action.

The necessity of action by the Congressional Committee may be more clearly perceived if a little notice is taken of what happens when the committee neglects to act, as at the present time. Changes are being

made in weights and measures, and made with legislation, with a great deal of it, but it is State legislation; for until the United States Congress exercises its constitutional authority, the subject is (like bankruptcy and a few other matters) left to the several States to do what they please with. When in Massachusetts in 1859 the wine quart was substituted for the beer quart in the milk business, it was done by a law of the commonwealth. The activity and ingenuity of local legislation is made conspicuous by a table inserted on the third page of the Standard Diary, as if it were of the first importance for the citizen to have at hand, exhibiting the weight of a bushel in pounds. This table is entered at the top with the names of our various crops, including coal and salt, and is entered along the side with names of the several States, including the District of Columbia; but it is so far from being either complete or correct, that a few illustrations of very recent legislation may be cited to show what is going on. On March 6, 1885, a law of Kansas was approved, fixing the weight per gallon of oils, as naphtha, $5\frac{3}{4}$ pounds; linseed oil, $7\frac{1}{2}$ pounds, and many others. Next day, March 7, 1885, another law of Kansas was approved to amend a law of 1879, which was itself amendatory of a law of 1877, about weights and measures. This illustrates the frequency of changes. The March 7 law fixes (in the absence of special agreement to the contrary) the number of pounds which shall constitute a bushel of each one of thirty-two different commodities. Two days later, March 9, 1885, a similar law of Indiana was approved, fixing the weight per bushel of thirty-one commodities, several of them the same as in Kansas, but some different. If sales are to be by weight, it is a needless complication to use a different weight unit for each kind of grain or seed. In Kansas the unit for native blue grass seed is 14 pounds, but the unit for English blue grass seed is 22 pounds. To use for the same commodity a different unit in different States is another needless complication; for instance, onions are to be sold in Kansas by a unit of 57 pounds, and in Indiana by a unit of 48 pounds, while in other States it is by units of 50, 52 and 54 pounds. The Indiana law of March 9 extended to some other things besides the bushel, providing that there should be 2,000 pounds to a ton of hay (which is different from the ton of the United States authorities), and 11 pounds to a gallon of sorghum molasses. Two or three weeks later, March 28, 1885, a law of Missouri was approved with regard to the measurement of stonework and earthwork in the absence of a special agreement. Section 2, treating of rubble masonry, after giving directions for obtaining the number of cubic feet, says: "This, divided by twenty-two (22) will be the amount in perches." But we know a perch as $1\frac{1}{2} \times 16\frac{1}{2} = 24\frac{3}{4}$ cubic feet, and the laws of Iowa (Section 2,050) fix a perch there at 25 cubic feet. A still more pernicious example was the action a little earlier of the Commonwealth of Massachusetts* estab-

* The original act and an addition to it, as quoted below, were passed in successive years by two different State governments, so that the action appears to be deliberate.

Acts and Resolves passed by the General Court of Massachusetts.

1883, Chapter 218.

An Act to Regulate the Sale of Coal by Measure.

Be it enacted, etc., as follows:

Section 1. In the sale by measure of coal in quantities less than five hundred pounds. the baskets or measures used in measuring the same shall be of a cylindrical form, of

lishing a bushel for coal 1 inch greater in depth and ½ inch greater in diameter than the United States bushel, and therefore between 18 and 19 per cent. greater in capacity. I am not aware of the existence of such a bushel anywhere else on earth. Another sample enactment of the same character, but more naïvely expressed, may be quoted from the Revised Statutes of Vermont; Sec. 3710 says: "One bushel and three-quarters of a peck shall be deemed a bushel of" several commodities named.

As the American people is evidently bound to have legislation on weights and measures, it might better be well considered, uniform and beneficial legislation by Congress, than be stupid, childish and contradictory legislation by forty States and Territories acting at cross purposes. The province of the local authorities should simply be to provide for the work of verifying and authenticating the implements used in trade to weigh and measure with, so that they may conform to the standard units which shall be fixed by Congress, and to attend to the detection and punishment of the use of fraudulent or forbidden weights and measures. The control is in our own hands; it is our unquestionable privilege to maintain the confusion of discordant regulations just as long as we find the subject uninteresting and dislike to give a little serious attention to securing better management; but if it is gratifying to our national pride that the United States led nearly all the Christian nations in introducing decimal coinage and abandoning the conflicting New England currency, New York currency, Pennsylvania currency, etc., it is humiliating that the United States is left to be among the last of civilized nations to drop grossly irregular weights and measures. The diversity of units in the different States may have done little harm when there was hardly any communication between the States, but with the modern development of intercommunication it is not to be tolerated. Professor

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the following dimensions in the inside thereof, to wit: Nineteen inches in diameter in every part, and nine inches in depth measured from the highest part of the bottom thereof, each of which shall be deemed to be of the capacity of one bushel, or nineteen inches in diameter in every part, and four inches and one-half in depth, measured from the highest part of the bottom thereof, each of which shall be deemed to be of the capacity of one-half bushel. Such measures, in selling, shall be filled level full, and every such measure shall be sealed by a sealer of the city or town in which the person using the same usually resides or does business.

SEC. 2. Every vender of coal who has in his possession a basket, box, tub, vessel or other measure not conforming to the provisions of the preceding section, or not sealed as therein provided, with intent to use the same or to permit the same to be used in measuring coal, sold or offered for sale, and any person who measures coal sold or offered for sale in any basket or other measure not conforming to the provisions of the preceding section, and sealed as therein provided, shall be subject to a fine not exceeding twenty dollars for each offense. Approved June 2, 1883.

1884, Chapter 70.

An Act in Addition to an Act to Regulate the Sale of Coal by Measure.

BE IT ENACTED, etc., as follows:

SECTION 1. The capacity of the baskets or measures mentioned in chapter two hundred and eighteen of the acts of eighteen hundred and eighty-three, shall be plainly marked or stamped thereon by the sealer of weights and measures. Coal sold in accordance with the provisions of said chapter two hundred and eighteen shall be delivered to the purchasers thereof in the same baskets or measures that are used in measuring such coal.

SEC. 2. Any person who violates the provisions of this act shall be subject to a fine not exceding twenty dollars for each offence. Approved March 10, 1884.

Hadley says in his book on Railroad Transportation (p. 18). "The extension of trade is forcing us into unity of money, weights and measures." His remark refers to international relations, but is no less true as between united states, and among the numerous pertinent illustrations of it is the treaty of peace and friendship just now concluded between the five republics of Central America. After a half century of independence they are preparing to unite again, and the 25th article of the treaty provides for a commission of two delegates from each State to present schemes for uniformity throughout all the States in many important matters, among them coinage, weights and measures. Though in many respects we are far in advance of these neighbors of ours, we may well take a lesson from them in this. The treaty says nothing about what system of money or weights and measures is to be agreed upon, and conservative people in the United States ought likewise to ask Congress to establish a uniform system of weights and measures with out saying what that system shall be, if they want to ignore the metric system. By shutting his eyes, however, to the invincible progress that the metric system has already made over nearly all the civilized world and is now making over the remainder, the conservative man can no more escape being swept along with it than the ostrich by putting its head under its wing can escape the pursuit of the hunter. The consul general of Costa Rica at New York has no doubt that the metric system will be the one that Central America will adopt. It was introduced about two years ago in Costa Rica, and is now in practical use there. Some thirty years ago it was ordered to be used in Guatemala, though with little effect. In Honduras, Salvador and Nicaragua metric weight is used in coinage.

The essential advantage of making the Congressional Committee the manager of reform in weights and measures is that by inaugurating a concerted movement throughout the country it can reduce the trouble and expense of a change to much less than they would be if the change were made in a hap-hazard way at the caprice of individuals, as may be seen by considering the nature of the change. It must be in a sense gradual: that is, in any one man's mind or in any one man's business it is necessarily gradual; it may take several years to get all the books of reference, measuring implements, price-lists, etc., of a single firm altered, or to finish a single work for which plans, specifications and contracts have already been made in old measures; but different men ought be changing simultaneously, so that one man or one business may not get through with its gradual process before another begins, and so prolong the annoyance needlessly; for a great part of the annoyance of the transition consists in twice measuring and computing quantities, using metric expressions and old expressions for the same thing. The less of this translating there is needed the better.

As to what legislation the congressional committee ought to decide upon, it should require the exclusive use of the metric system in all government business after some date fixed a few years in the future. We now carry in our pockets U. S. subsidiary silver coins weighing 1 gram for every four cents, but U. S. silver dollars whose weight we awkwardly describe as 412½ grains; let all the coin weights be expressed in grams

and stamped on the coins. In our post-office, at the foreign letter window, there is now a balance for weighing letters per 15 grams, but at the domestic letter windows are balances for weighing in ounces: let all be made metric, even if it should allow us to send six per cent. heavier letters. In the medical department of the U. S. Marine Hospital service the metric system has been used for some years, while the army and navy surgeons have continued to use old weights and measures; let all Uncle Sam's doctors alike use the metric units. In the weather bureau metric values are given on the international charts, but only old units on the ordinary charts; let them all use metric units only. On the U. S. Coast and Geodetic Survey, the U. S. Geological Survey, the U. S, Lake Survey and the surveys under the Mississippi River Commission, there has been very extensive use of the metric system, but the U. S. public land surveys have used only old measures: let them all have the same unit, the meter. In the publications of the last U. S. census some of the information is in metric terms, some in old; let the next census be uniformly metric. The transition process of using conflicting systems does not want to be protracted. Where the metric system has already been introduced in government affairs, it has been mostly by the discretion of the officers in charge, and it might be introduced from time to time into other government departments at the discretion of other officers; but an act of Congress requiring its use in all government business within a suitable and sufficient time would make sure of the action of all the government officers, and of their harmonious and substantially simultaneous action. Moreover, government transacts so much business and deals with so many citizens that any system of weights and measures it adopts is bound to become familiar to a large part of our people. Action positively showing that the metric weights and measures are going to be used exclusively, after a certain date, throughout all the ramifications of its immense business, will naturally stimulate prudent men to plan for managing their own transactions after that date conveniently with the government system, just as prudent men to-day, though seeing the advantages of the metric system, are constrained to adhere to the old units that nearly all of their neighbors' transactions and of the government's transactions are made with. Our citizens will thus have a motive for changing in their private business simultaneously. Government, better than most organizations or corporations, can venture to take the initiative.

The exclusive use of the metric system in government business and especially in the custom house, as a step preliminary to the popular use of the system, has been tried with gratifying success in various countries among those that have more recently adopted the metric system; for instance, in the Argentine Republic as mentioned in our committee's report. There the custom house business was for some years conducted in metric units, while they were not used in commercial transactions generally; but a change not only was ordered to be made, as the committee states, but actually has been made, and ordinary business is now done there in metric units.

The policy of introducing the metric system for exclusive use in the government service was proposed in the report of the Congressional Committee

on Coinage, Weights and Measures in 1866. It has been recommended in many quarters, among others in the draft of a memorial to Congress prepared by a committee of the American Society of Civil Engineers in 1877 (printed in A. S. C. E. Proceedings, Vol. III., p. 47). It was pursued in the introduction of a bill from the Committee on Coinage, Weights and Measures in the Forty-eighth Congress, 1884, and in its renewal by Mr. Everhart in the Forty-ninth Congress in 1886, requiring the exclusive use of the metric system in the government departments after about five years; but the silver question absorbed attention, so that weights and measures had to wait. When the Committee of the Western Association of Architects gets its proposed appeal ready for the Fiftieth Congress, which will be in session next winter, our Committee on Weights and Measures would do well to circulate among the members of the Boston Society of Civil Engineers blank forms which we could sign, expressive of our opinions in favor of reform in weights and measures, or against it if desired, so that our judgment may be ascertained and made known, and that our influence, whatever it is, may also be properly exerted upon current events in which we have so much reason to be interested.

ANNUAL ADDRESS.

BY CHAS. LATIMER, RETIRING PRESIDENT OF THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read at the Annual Banquet, March 15, 1887.]

Fellow Members of the Civil Engineers' Club of Cleveland and Welcome Guests:

Another year of our history is past and recorded, and according to our custom we are gathered around the festive board, all save a noble trio, a Devereux, a Lawrence, a Whittlesey; again permitted to assemble after the labor of the year in social converse, to take each other by the hand, to revive the memories of past days, and with unabated interest in our Society, we are ready to seek hereafter with fraternal emulation under a new administration to surpass our former records. In reviewing the work of the engineering world during the past year, I have been forcibly reminded of the importance of a good foundation. What is a beautiful structure without it? It is like a whited sepulchre, all fair without, but rotten within. How the Scriptures warn us about it. The foolish man is likened unto one who built his house upon the sand, and the wise unto one who founded his upon the rock, and the winds blew and the floods came and it fell not, because it was founded upon a rock. Now, what does this teach us? To go to rock every time, if possible, for our foundation, and to bore into that and ascertain if it is but a shell. But the foundation is not all. There is the material. The responsibility is great here, for however good the foundation, if there is a crumbling stone, a poor quality of iron, unseasoned or prematurely cut timber, failure must be the result. Again, what will the best foundation and material avail without the skilled workman? Unless we have all these the verdict is "shoddy!"

Grave and reverend veterans of engineering, may it never be your evil

fortune in these days of flood and disaster on land and sea to have, like a stroke of lightning through your heart, the news of the fall of a bridge, of a tower, the breaking of a shaft or rail, the bursting of a boiler, and to feel that you alone are responsible. May none of you have to recall your neglect to put your pier or abutment upon the rock when it might have been done so easily, or to remember some other act of unfaithfulness, or neglect to build aright.

Young engineers, full of hope, ambitious of distinction, do not let love of money so enthrall you that your profession shall not stand first, and beginning now, let it always be said of you what may be said of some; "He was faithful to his trust."

I am reminded here that in the closing days of the last administration and the opening of the new, a committee was appointed to take in hand the subject of public works. A scheme was outlined, it is not dead, nor sleeping. That scheme awaits the hour when as a people we shall build our own railroads, highways, telegraphs and great structures, when no pent up Utica shall contract our powers, when there shall be no scrimping of foundations, no narrowing of walls.

In the direction of the subject of public works and of government control, this year and administration have been distinguished by the passage of a most remarkable bill, called the "Inter-State Commerce bill." I do not know any act of legislation so important to the interests of all of us as this, and I do not know any which should be more gladly hailed by the whole country as a step in the right direction, however crude and unsatisfactory it may appear. Yet it looks wonderfully well for a first shot. To those who have observed the working of railroads for the past fifteen years, it has become plainer each year since 1873, that the governmental hand of the people must sooner or later be stretched out to snatch the railroad management from utter chaos. Since 1873 there has been a systematic movement towards consolidation, and for this stupendous efforts were put forth to bankrupt the weakest by rate wars; the result was that a great number of the railroads were thrown into the hands of receivers, were entangled in the meshes of the law, or were sold out for small sums and made part of large systems. This caused a deadly struggle to prevent bankruptcy by the reduction of wages and retrenchment, and had its culmination in the fearful railroad riots of 1877 and the formation and enlargement of labor organizations. A revival of business in 1879 with a great boom in prices brought temporary relief and peace, and the establishment of a gigantic pool of all trunk lines: but the boom being fictitious and the pool short-lived, 1882 brought renewed strife. The pool shivered and struck colors on the construction of the West Shore Railroad and the extension of the Lackawanna, and for two years the fight was renewed with redoubled energy, and the whole system, with but little exception, was only saved from wreck and the receiver by the revival of the pool in 1885. The leaven had worked, however, and legislatures and Congress with representatives of new views appeared. Labor organization also tended to consolidation. The societies of labor suddenly arose to eminence, bidding fair to unite in one general organization to meet a combined pool of all railroads in the land. Amid this

Titanic strife, when it seemed as if all the railroad and labor systems of the country would be involved in irretrievable ruin and the strike and boycott seemed to bid fair to be the rule instead of the exception, the "Inter-State Commerce bill" came like the booming of the first gun on the side of the people in Congress assembled. Shivering the pool by legal enactment, abolishing privileges, insisting upon equality for all men in business, declaring against monopolies and providing a penalty that if "these laws be not faithfully performed, we will lay hands on you, fine and imprison you." The passage of the Inter-State Commerce bill is the dawn of a brighter day. The law may be imperfect, it may require changes both ways, but it means business, and there is but one way to do, obey it in the letter and the spirit, whatever may come. That same legislation which prevents one class of citizens from gaining or obtaining advantages in business over another must be continued until its ramifications extend to all classes of trade, when the law requires and enforces perfect equality in the dealings of all corporations, the employés and patrons, then combinations for greedy purposes must cease; and when greed is chained then monopolies die, and the strike and the boycott die with them. In the Inter-State Commerce bill we have the beginning of the end, and the result cannot fail to be beneficial to our profession and the whole country.

In my judgment that Inter-State Commerce bill should have provided that it shall be unlawful for any railroad company to run any locomotives or trains or to do any work in the shops or offices of the same on Sunday, except such works of necessity as emergency may clearly demand, thus showing the railroad companies that the people in Congress assembled declared for the law of the God of our fathers, and showed an example of obedience to law as government and people. and declared against the slavery now existing on our railroads, when it is unsafe for a man's official head for him to obey the law of God in this respect. Seven days of constant work, with twelve hours' rest, will soon wear out any man, however strong; but seven days of work of fifteen hours, as we frequently see it, will destroy the life of the individual and dwarf the nation.

The past year has been one of extraordinary activity, mental as well as physical. There have been but few hands necessarily idle, and yet never in the history of modern times have there been so many idle of their own determined will. The workmen of the world, and especially of the new world and of our own country, have been, and are, stirred to their profoundest depths. Is there a cause? Has faith fled? Have morality and religion waned? Is it a sham that temples to the living God are going up on every hand? With every advance of the steel rod, the church and the school-house are the first structures erected. There is a cause; but faith is not yet dead, nor have morality and religion left us. The nation is but beginning to feel the grandeur of its resources. The possibilities for sudden wealth are so enormous that the people of all lines of work are in a feverish state of excitement, each feeling that he has scarcely his proportion. Tied down to a narrow, circumscribed circle, the workman chafes at the fact, and longs to grasp more of the golden apples of

this natural Hesperides. In this universal greed, law is temporarily ignored. The laborer, seeing the colossal fortunes called up, as it were by the lamp of Aladdin, partakes of the spirit of greed, so much so that he is willing, and even often anxious, to work seven days in the week; more willing to protest against a diminution of pay, or to demand more, than against being required to break God's law.

I have asked, and have been asked many times, "What is the cause of this great unrest in the labor world?" These are some of the answers: over immigration; ignorance of the laboring classes; man's inhumanity to man; monopolies; combination of capital; stock gambling; greed; over work; intemperance; great land grants to few persons, and so forth. This is a long list, and the causes are mixed in these statements, but all show that there is a profound dissatisfaction and it must be treated with respect and consideration by all men. There is some great change in political economy at hand for us, and to my view the solution is a grand one for the advancement and excellence of public works. It does seem an absurdity that the wheels of the whole railroad system of the country, the very vertebræ and arteries of trade and the life of the nation, can at this time be suddenly stopped upon the simple dispute between men and one officer as to whether two or three men are necessary upon a freight train, or upon the question of the discharge of one man. Is it possible that the whole trade and prosperity of this country may be paralyzed in a moment upon the dictum of one man, or set of men? This is virtually possible this day. By what miserable combination of circumstances has this come about? Crimes of the most fearful kind have been committed in the past and are now being committed daily, crimes which might cause angels to shed floods of tears, and yet they pass unnoticed and unconsidered save as items in a newspaper.

Bible readers may well remember the almost complete annihilation of the tribe of Benjamin for the terrible brutality to, and murder of one poor woman, whose body was cut into twelve pieces, and one portion sent to each tribe. The combination was the most extraordinary retribution for a single outrage, the most brutal known to the human race. We have arrived at a moment in the world's history when, for the discharge of one man, the trade of a nation may be paralyzed—a stupendous power, unheard of in the history of nations before. It should be no more possible for one man, or set of men, among the many on railroad systems, to produce this paralysis of trade than that the earth should be loaded with dynamite, and that it should be in the power of one man to touch a button, and by electricity blow the planet into atoms.

Nothing, it would seem, but important governmental or popular action, I mean congressional action, can now bring peace. A commission should be formed at once to take up and adjudicate every strike and decide every great dispute between railroad officials and men on the spot. If we had this to-day, we should not have a district paralyzed. But this, with the Inter-State Commerce bill, is but a forerunner of the inevitable, the purchase of all railroads and telegraphs and the construction and management of them in the future by the government of the people.

One thing is certain, any discipline not founded upon the acknowleag

ment of the rights of every man, however poor, to the same freedom we enjoy ourselves, and not founded upon mutual esteem and human kindness, can only be maintained by force, and commercially will produce less, and will cost more and be more fruitful in disaster than the discipline of justice and mercy. Our profession is pre-eminently one of civilization and Christianization.

I cannot forbear to allude again to a thought uttered long ago, which, though seemingly referring to a tyrannical rule, is the ancient prediction that the Most Beneficent "shall rule the nations with a rod of iron." In the beginning of great New England enterprises, a minister preached a sermon in Boston on the moral and Christianizing influences of the railroads. A president of a projected railroad, with true Yankee ingenuity, at once seized the thought and had a large number of copies of the sermon printed and scattered among the people, moving church people to consider the great moral and Christianizing influence of the building of the Western Railroad of Massachusetts, of which he was the projector. Let us consider the great honor and importance we bear as workers in building up a Christian kingdom where the princes and priests are the people, and the king is the Lord himself, and let all our work be done as unto Him. It would surpass the boldest flight to say what the continent shall be, but I cite one among the wonderful predictions concerning our country. In 1745 the Marquis d'Argenson wrote: "A day will come when we will go to a populous and well regulated city of California as one will go in the stage-coach of the city of Meaux." This was a remarkable prediction, but he could scarcely conceive of what did take place a short time ago. A train left New York and arrived in San Francisco in 83 hours 32 minutes and 7 seconds. Forty-seven years ago I stood on the deck of a ship in the Golden Gate and saw the deer and elk grazing on the hill north of San Salito. Then in 1842, when but a boy, I said to myself, "Here will be some day the great highway from New York to China." But I did not grasp half of that which I now see accomplished by the engineering spirit of the people, Four great trunk lines from the Atlantic to the Pacific, and the distance of 3,500 miles traversed in a little over three days.

And yet the movement is but in its infancy and only a few years will pass till there will be as many trunk lines between the cities of New York and San Francisco, I might say to Behrings Straits, as there are between New York and Chicago. Why should I stop here? And why may I not say that our old system of reckoning our watches shall pass away and old time shall be no more? We may hear the announcement of the porters, "express for Jerusalem, Ghizeh, Pekin, Paris, London." With new discoveries and devices we may surmount all difficulties and run westward 23,000 miles in 230 hours. It is entirely within bounds to say that 100 miles an hour may be reached and that there need be no stops at all, but that transfers of passengers will be made by local or accommodation trains running alongside of the fast trains.

A civil engineer, a personal friend of mine, has already designed seven aerial ships and calculated every detail. These are not mere balloons, but veritable ships, with machinery and all the conveniences of the palace steamboat of the Mississippi, or of the grand ocean steamships.

They will take a regiment of soldiers, with their provisions, ammunition and park of artillery, with shots, shells, etc. Only the funds are needed to carry on the work.

Doubtless many will at first fear to take these fast trains and air ships, but they will soon become accustomed to it, and they will be preferred to the slow 60 miles an hour accommodation.

When we shall have the collapsing of an air ship or two, or the derailment of a 100-mile an hour train, we will soon understand how to put safety guards, and when a false economy will not be known, the managers will not be permitted to reduce the labor below the danger point in order to declare a dividend on watered stocks.

Disasters are great teachers. Two fearful holocausts in this country, one at Rio on the Baltimore & Ohio, the other at White River in Vermont, and a wreck yet more terrible near Boston, teach us many things, among others: Let us not encourage our men to drink whiskey by keeping open saloons at the eating stations 2d. Let us not use tinder boxes for cars, that is sleeping and day coaches, varnished and painted to burn as quick as celluloid or gun cotton. 3d. Do not use open fires. 4th. Do not use explosives for fuel or light on cars. 5th. Put safety guards for re-railing trains at each side of every bridge. 6th. Do not overwork men. 7th. Rest man, beast and material one day in seven. 8th. Be sober, be vigilant. Some recent disasters point plainly to the necessity of electric lighting, and heating, which must occupy the highest talent of the educated or natural engineer, and which presents a prolific field for the talent of the members of this Club, especially those who represent those branches.

There have been some marvelous changes in rolling stock on railroads latterly. The great rate wars have forced engineers of every branch to think. One of the evolutions is that of using a locomotive which should overcome the disparity in grades. The high-grade road has already required and used a one hundred and fifteen ton locomotive equipped with tender ready for service. This is the great Decapod of the Northern Pacific.

The bridges of ten years ago were found too light for the consolidation engines of 65 tons. Roads are scarcely equipped with the new bridges to suit the new engines when again the engines are increased.

The freight 10-ton cars of ten years ago are now dwarfed by the 25-ton cars. These must soon force the 100 pound per yard steel rail into use. Heavier bridges, machinery, rails, heavier cars, are now the order of the day. With this comes faster speed. Soon grade crossings, either over railroads, over streets or highways must cease. Our distinguished member and ex-President, Charles Paine, had locomotives built which made the run from Buffalo to New York, over 400 miles, averaging over sixty miles per hour, including all stops. The speed reached as high as 87 miles per hour. The most wonderful strides have been made in speed of steamships. The Etruria has just made her run of 3,128 miles at the rate of 22 statute miles per hour, and a ship is now being built which is to cross the ocean in a little over five days.

The great war ships of England are now made to resist the penetrating power of the Armstrong and Krupp guns. When I first entered a

man-of-war in 1841, a 64-pounder weighing 6 tons was a monster. A 12-pound charge of powder was immense. Now 115-ton rifled guns with a charge of a ton of powder, and with penetration of 30 inches iron at half a mile must soon be superseded. No sooner do we build an impenetrable ship than a new penetrating gun or shot arises, and the ship is but a hulk, and it goes like our locomotives, rails and bridges. Our country has quickly and wisely profited by the experiments of Europe, without expense possibly, though we trust not. It is time for us now to make something with a larger bore than all those mentioned because we have the last word.

Some of our engineering friends were rather surprised by my advancing the idea that in a short time we would build railroad bridges half a mile span. I might fill a page with similar possibilities, but I wish now to mention that one of our members has already planned a bridge of 2,800 feet in which every detail is worked out, and from my knowledge of his ability there is no question whatever in my mind of its complete success.

With regard to the "new Chapin pneumatic iron," our worthy member and distinguished bridge engineer, Gustav Lindenthal, of Pittsburgh, writes me: "In the race for producing cheap steel in large masses, the production of iron in large masses and in a more scientific manner had been almost neglected. The rotary puddling furnace was the only attempt at improving puddling, but it was not commercially successful in this country, and little more so in England and on the continent. But recently a more rational and thoroughly scientific and mechanical process of producing wrought iron has been tried, and it is in successful operation now in Bethlehem, Pa., steel works. Generally speaking, it consists in refining molten pig iron by the air blast in a Bessemer converter and then transferring the charge to rotary puddling furnaces, having an iron ore lining, in which the metal is brought to 'nature' in about five minutes. From the rotary, or 'balling' furnace, the ball of agglutinated iron is taken to a 'Winslow squeezer' and then it is worked down into muck bars in the usual manner. The process can be adjusted to any kind of pig iron, high or low in silicon, carbon, sulphur, or phosphorus, and the product will always be a dense, fine fibrous, very ductile wrought iron, with an ultimate strength of 60,000 to 70,000 pounds to the square inch, 30,000 to 40,000 elastic limit and 15 to 25 per cent. elongation in eight inches, and a corresponding reduction at point of fracture. The quality of the wrought iron depends on the amount of work put on it, but generally speaking, it can be stated, that the quality of the wrought iron produced by the Chapin process will be forty per cent. better than wrought iron produced by hand puddling from same grade of pig iron, and the cost of production will be about six dollars less per ton than by hand puddling. It is obvious that such fine wrought iron will be found preferable to open hearth steel for all structural purposes. The iron has been tested already, but more extended tests are still going on."

I must speak of another remarkable thing. Three years ago, I alluded to the possibilities of the future in the manufacture of aluminum for rails and bridges through the instrumentality of electricity. The Cowles

Brothers, sons of Edwin Cowles, have discovered a new method of making aluminum bronze, and the great works at Lockport are now turning out a considerable body of it. This has occurred within the year. The Phœnix Iron Company, of Germany, Krupp's greatest competitor, report that enough of the Cowles aluminum iron alloy added to their basic Siemens-Martin steel to make one-fifth of one per cent. of contained aluminum gives them 112,000 pounds tensile strength to the square inch, with 12.5 per cent. elongation. The best results previously attained with this steel without aluminum was from 96,000 to 98,560 pounds to the square inch. London *Engineering* says: "Messrs. S. French and B.M. Plumb, European agents of the Cowles Electric Smelting and Aluminum Company, of Cleveland, have a forged bar of aluminum bronze, containing 5 per cent. of aluminum, which has broken in the testing machine at a strain of 36 tons per square inch of original section, and with 60 per cent. elongation. (English tons, equivalent to 80,640 pounds.) A bar of this metal forged, bent and broken in company with a similar bar of Siemens-Martin basic steel, exhibited characteristics identical in every respect except color."

If time would permit, I would gladly touch upon the many wonderful undertakings in our profession, but must content myself with speaking briefly and generally of that great problem of interoceanic communication, upon which the eyes of the whole civilized world are now fixed.

THE PANAMA CANAL AND OTHER GREAT CANALS.

This great undertaking is not an enterprise of to-day, but it flashed across the brains of the bold navigators of the fifteenth century as they stood upon the shred of land that separated the two oceans. The Abbé Gregoire of France, nearly a century ago, made a remarkable prediction as follows: "The American continent, the asylum of liberty, is moving towards an order of things which will be common to the Antilles, and the course of which all the powers combined cannot arrest." This vigorous language is crowned by a prophecy of singular extent and precision, when, after dwelling on the influences at work to accelerate progress, he foretells the eminence of our country: "When an energetic and powerful nation, to which everything presages high destinies, stretching its arms upon the two oceans, Atlantic and Pacific, shall direct its vessels from one to the other side by an abridged route—it may be in cutting the Isthmus of Panama; it may be in forming a canal communication, as has been proposed, by the river St. John and Lake of Michigan—it will change the face of the commercial world and the face of empires. Who knows if America will not then avenge outrages she has received, and if our old Europe, placed in the ranks of subaltern power, will not become a colony of the New World?" Thus resting on the two oceans with a canal between, so that the early "secret of the strait" shall no longer exist, the American Republic will change the face of the world, and perhaps make Europe subaltern. Some of you will remember the visit of M. de Lesseps to this country in 1879 and the reception given to him by the American Society of Civil Engineers. This was just at the beginning of the movement to build the canal. At that meeting, I asked M. de Lesseps what bearing the questions involved

in the Monroe doctrine would have finally upon the enterprise. This aroused his excited response, "We might as well have to ask the United States for permission to build across Canada." Directly after this interview, I, with a friend, met General Garfield—it was a year before his election—and detailed the conversation to him in order to settle the question between my friend and myself; I saying that the canal must be controlled on this side of the ocean, he taking the view that there was no reason why France should not control it. General Garfield said emphatically, "We cannot permit a European power to control the isthmus canal under any circumstances." How remarkable then is the prediction of the Abbé Gregoire nearly a century ago, before the declaration of that doctrine called the Monroe doctrine; the advice and work of the great British statesman, Canning; and here is the *casus belli* of the old world against the new, which will surely bring to pass the fulfillment of the prophecy of the wise Abbé.

When we see looming up in the near future the construction of the Nicaragua Canal, and the construction of that other grand enterprise of our deeply lamented Eads, cut off as it were while I speak, the benefactor of the nation, we are aroused to contemplate the great future of this new world, and the certainty of the call of many of the members of this Club to high destiny in meeting the glorious exigencies of the coming time. I think that I can see Eads now as he closed his eyes in bitter contemplation of the thought that he must die and not witness the fruition of his great hope of transporting the largest ships across the Isthmus of Tehuantepec. The broken hearted Columbus as he was taken back in chains to the old world to which he had given a new, as he lamented his wretched fate seemed to hear a heavenly voice saying, "Oh, man of little faith, thy name is written on the rocks." The voice of a grateful nation will say to Eads, "Oh, man of faith, as long as the great father of waters, whom thou didst defend, and deepen, shall rise and pour its streams from the icy mountains of the North to the Spaniards' land of flowers, so long shall thy name be engraven on the hearts of thy countrymen."

It has been the opinion of many engineers that the Panama Canal will never be finished, that the cost will run up to 400 or 600 millions of dollars. I am not of this opinion. I feel confident that it will be finished from ocean to ocean within a very few years. I believe that the Nicaragua Canal will also be finished and make the most beautiful and delightful transit imaginable through a country of unexampled loveliness, through a charming lake of pure water whose height above the ocean is the same as the height of Chautauqua is above Lake Erie, that is 742 feet, and the cost may not exceed $100,000,000. I believe that the Eads ship railway across the Isthmus of Tehuantepec is practicable and will also be built.

Let us turn to another prediction from Aleman, the Mexican historian: '*Mexico will be, without doubt, a land of prosperity from its natural advantages, but it will not be so for the races that now inhabit it. As it seemed the destiny of the people who established themselves therein at different and remote epochs to perish from the face of it, having hardly a memory of their existence; even as the nation which built the edifices of Palenque, and those which we admire in the Peninsula of Yucatan, was*

destroyed without its being known what it was, nor how it disappeared; even as the Toltecs perished by the hands of barbarous tribes coming from the North, no record of them remaining but the Pyramids of Cholulu and Teotihuacan, and finally, even as the ancient Mexicans fell beneath the power of the Spaniards, the country gaining infinitely by the change of dominion, but its ancient masters being overthrown, so, likewise, its present inhabitants shall be ruined, and hardly obtain the compassion they have merited, and the Mexican nation of our days shall have applied to it what a celebrated Latin poet said of one of the most famous personages of Roman history, 'Stat Magni Nominus Umbra,' nothing more remains than the shadow of a name illustrious in another time. May the Almighty, in whose hands is the fate of nations, and who, by ways hidden from our sight, abases or exalts them, according to the designs of His Providence, be pleased to grant unto ours the protection by which He has so often designed to preserve it from the dangers to which it has been exposed." What a remarkable prediction it is and how plainly it points, and yet, although it is so plain, let not the idea of conquest enter our minds. What may be, and we hope will be, is that in the future those neighbors of ours may be sharers with us in the blessings of the strongest of all governments founded upon mutual respect and esteem, resulting from our earnest emulation to work for what is best and wisest for the people of the world.

While the great network extends its meshes over a redeemed wilderness to the West, the silent, steady march of the same steel rod moves southward on the great backbone of two continents, reaching out with its vertebræ over port and bay and river, until it stands out on the frowning promontory at the remotest regions of the South.

What glorious fields lie open to your view and to the great possibilities of your profession to the broadest signification of the word "engineer!"

In building these vast monuments to the skill of the present age, let us not forget to notice in the footprints of time the work of a race so long vanished that it is claimed, and so far accepted by some, that no trace remains of its origin, its language, or its descendants, whose ruins bear evidence of a knowledge in many respects greater than ours. Let us learn to build even wiser and better than the forerunners of the Toltecs and Incas; those who were swept away by a mighty flood as unworthy of rest upon the earth, ages before the progenitors of all that we now may name had appeared upon the scene. The destiny which the historian Aleman predicts for his own people is that of all of the nations south to the uttermost limits of the land.

With so glorious an inheritance, with so brilliant a future, with such heavenly blessing, may we so apply our hearts unto wisdom, so faithfully build as unto Him who has honored this people that the prediction of the Mexican historian of his own nation, that "nothing more remains than the shadow of a name illustrious in another time" may never be fulfilled in ours; and let his concluding prayer fill our hearts: May the Almighty, in whose hands is the fate of nations, and who, by ways hidden from our sight, abases or exalts them according to the designs of His Providence, be pleased to grant unto our nation the protection by which He has so often preserved it from the dangers to which it has been exposed.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

JUNE 15, 1887:—A regular meeting of the Boston Society of Civil Engineers was held at Room 27, Boston & Albany Railroad Station, Boston. The meeting was called to order at 7:45 P. M., 30 Members and three visitors present.

In the absence of both President and Vice-President, Prof. G. L. Vose was elected president *pro tempore.*

The record of the last meeting was read and approved.

Messrs. Nelson Spofford and George H. Barrus were elected Members of the Society.

The following were proposed for membership: Mr. Lucian A. Taylor, of Worcester, recommended by A. F. Noyes and A. S. Glover; Mr. Erastus Worthington, Jr., of Dedham, recommended by G. F. Swain and Dwight Porter.

The Government submitted a report recommending that the printing of the records of the meetings as ordered April 21, 1886, be discontinued. On motion of Mr. Manley, the recommendation was adopted.

On motion of Mr. G. S. Rice, it was voted to omit the regular meetings of July and August.

Announcement was made of the death of Mr. George A. Parker, an Honorary Member of the Society, and the Government was requested to appoint a committee to prepare a memoir.

Prof. Vose presented to the Society, on behalf of Mrs. William Parker, a very fine crayon portrait of her late husband. In presenting the portrait, Prof. Vose gave the following sketch of the life of Mr. Parker:

Mr. William Parker was born in Perth Amboy, New Jersey, July 18, 1807, and was the son of the Hon. James Parker, a prominent man in public affairs in the early part of the century. At the age of fifteen years he was sent to Capt. Partridge's Military Academy, at Norwich, Vermont, where he studied civil engineering under the late Edwin F. Johnson. After spending two years at this place he commenced active work upon the Juniata Canal. Later he was employed upon railroad work near Germantown, where he made the acquaintance of Wm. S. Whitwell, through whose recommendation he was appointed assistant engineer to Col. John M. Fessenden, who was then engaged upon the construction of the Boston & Worcester Railroad, upon which work he remained until its completion. In 1836 he was offered the position of associate engineer upon the Eastern Railroad, but he declined this to become chief engineer of the East Florida Railroad. He was also at the same time connected with other works of internal improvement in that part of the country. Soon after, he was appointed Superintendent of the Boston & Worcester Railroad, a position which he held for eleven years. For the next five years he was Superintendent of the Baltimore & Ohio Railroad. He then returned to Boston and took the superintendence of the Boston & Lowell Railroad, and acted at the same time as consulting engineer for various other important works. In 1860 he was appointed engineer and Superintendent of the Jersey City water-works, from which position he was called, after a few months, to the general management of the Panama Railroad. Upon this work he remained until his death, in 1868.

None of our early engineers have left behind a more enviable reputation than Wm. Parker. He was equally skillful in the construction and in the management of railroads. "He was," says Mr. Samuel Nott, "a model engineer and business

man, and one of the best men I ever knew." No man ever appreciated more fully the important relation between the manager and the subordinate than Mr. Parker did. He had wonderful power over men, which came from a deep seated sentiment of justice and fairness which guided all his movements. With such a man "strikes" were impossible. He never left a position without receiving a forma expression of good will from all persons with whom he had been associated. He aimed at the fullest discharge of his duty to employers and employed alike. His death at Panama was regarded as a public calamity. "No life," says one who knew him well, "touched his without being made better by the contact."

Let us hang his portrait upon our walls, and while his face looks down upon our deliberations, let us look up to him, as to one who was faithful to every trust committed to him, and who was honest, loyal, just and true.

On motion of Mr. FitzGerald, the Secretary was directed to convey to Mrs. Parker the thanks and appreciation of the Society for her valued gift.

On motion of Mr. Manley it was *voted:* That in printing a new list of members of the Society, the class of Corresponding Members be omitted.

Mr. Edward S. Philbrick read a paper entitled, "The Land Slide of May 1, 1884, on the Boston & Maine Railroad, at Dover, N. H."

A general discussion followed the reading of the paper.

Professor Vose described some peculiar designs of railroad bridges which had come to his notice, which was followed by an informal talk upon bridges.

[*Adjourned.*] S. E. TINKHAM, Secretary.

WESTERN SOCIETY OF ENGINEERS.

JUNE 7, 1887:—The 237th meeting was held at 8 P. M., President Artingstall in the chair.

The minutes of the preceding meeting were read and approved.

Application for membership was received from A. N. Talbot, Assistant Professor of Mathematics and Engineering, University of Illinois, Champaign, Ill.

Mr. Parkhurst, for Committee on Construction, reported that the Committee recommended that the paper on Hydraulic Motion, by Mr. McElroy, be published in full, and be discussed after publication.

The report was adopted.

The Secretary presented a bill for $178 from *The Railroad Gazette*, being the May assessment, first call, for publication of the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

The bill was ordered paid.

A paper, by Mr. C. H. Hudson, the Change of Gauge of Southern Railroads in 1886, was read by the Secretary and Mr. Lundie, and discussed by the Society.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

At the next meeting papers are expected from Mr. Zellweger and Mr. Lundie.

ENGINEERS' CLUB OF MINNESOTA.

APRIL 22, 1887:—Regular meeting at City Hall, Minneapolis, at 7:30 P. M. Members present, President Sublette, Messrs. Riggs, W. W. Redfield, Deterly, Houston and Pardee.

As a report of Committee on Library, Mr. Redfield stated that after having communicated with Secretary Prout, it was found that the association JOURNAL could be procured from the beginning at a reasonable cost. The Club accepted an offer from Mr. Redfield donating $7. to be used in procuring back numbers of the JOURNAL, the balance of money needed to be furnished by the Club. The Club

also accepted Mr. Houston's donation of a year's subscription to *Engineering*, and voted thanks to each gentleman for the donation.

On motion Messrs. Houston and Pardee were appointed a committee to look up delinquent Members and report at next meeting.

A motion was made to alter the Constitution of the Club and was laid over till a future meeting. The discussion of Wire Rope was again deferred.

[*Adjourned.*] WALTER S. PARDEE, Secretary.

MAY 13, 1887 :—Regular meeting 7:30 P. M. Members present, Mr. President, Messrs. Sturtevant, Wm. W. and C. L. Redfield, Riggs, Cappelen and W. S. Pardee.

Minutes of last meeting were read and approved. The Committeee on New York Harbor and also on Delinquent Members made no report.

Messrs. James Rigby, J. E. Turner and T. Crary were elected to membership.

The minutes of the meeting of Board of Association Managers held at Chicago, Ill., April 15, 1887, were read, and on motion the Club authorized the Board to call a convention of delegates for the purposes set forth in their recent communication.

Several members took part in the discussion for the evening on Wire Ropes.

Mr. J. E. Snyder's name was proposed for membership.

The President promised a paper on Land Subdivision, to be read at an early date, and urged the Members to bring reports of their daily work.

[*Adjourned.*] WALTER S. PARDEE, Secretary.

JUNE 10, 1887:—Regular meeting Civil Engineers' Club of Minnesota, City Hall, 7:30 P. M. Members present, the President, and Messrs. Houston, Deterly, Wm. W. and C. L. Redfield, Cappelen, Rigby, Riggs, De Le Barre and W. S. Pardee.

The Librarian reported the receipt of the latest edition of Trautwine's Engineers' Pocket Book; the Club voted thanks and notice sent to Mr. Trautwine.

The chairman of Committee on Delinquent Members reported sundry dues collected.

The club took action on the remainder of the delinquent list, and revised the whole list of members, and ordered 50 copies printed for distribution.

On motion, 500 postals were ordered printed.

On motion, the President appointed Messrs. De Le Barre, Pike and Newman a committee to revise the Constitution.

Messrs. J. E. Snyder and A. W. Burnham were proposed for membership.

The programme of literary exercises was the Polytechnics of Europe, by F. W. Cappelen. Beginning with an enumeration of European scientific schools, he spoke of the Dresden institution and its departments, the students of which in the physical department are obliged to be well informed in the common grade of knowledge before they can enter the college. The civil engineers' course is completed in five years. At the end of the first two years occurs the first examination, and at the end of the next two the second examination. Both examinations are rigid, and the amount of work required throughout the whole course is very large, and few, if any, students are able to do all the work so as to be certain of being informed on all the work gone over. The manner of study is optional, the examination being the actual test of the amount of work done. The talk was well illustrated by careful drawings.

On motion the President appointed Messrs. Rinker, Cooley and Van Duzee a committee to draft resolutions relative to the death of Franklin Cook, and the Secretary was ordered to send an engrossed copy to the relatives of the deceased.

[*Adjourned.*] WALTER S. PARDEE, Secretary.

JUNE 24, 1887:—Special meeting of the Engineers' Club of Minnesota, 7:30 P. M., City Hall. Members present, President Sublette, and Messrs. Houston, Wm. W. and C. L. Redfield, Cappelen, Pardee.

Minutes of the last meeting read and approved.

The Secretary read the obituary prepared by the Committee relative to the death of Franklin Cook, and on motion the Secretary was instructed to send a copy to the members of the bereaved family, and also to the JOURNAL OF THE ASSOCIATION.

The Secretary read an invitation from the American Society of Civil Engineers to attend the annual convention, and the Club appointed President Geo. W. Sublette a delegate to attend the same—the expenses of the delegate to be borne by the Club.

The President stated that one object of this meeting was to consider the feasibility of having an excursion. On motion of Mr. Houston a joint committee was appointed to assist the Secretary in finding the wishes of the Members regarding the proposed excursion, and also of the St. Paul Club.

The President appointed on the first committee Messrs. W. W. and C. L. Redfield, and on the second, Messrs. Houston and Cappelen.

On motion the President appointed Messrs. Cappelen, Pike, Houston, Redfield, Pardee a standing committee on Tests of Materials, to confer with the State University authorities with reference to a series of tests of local materials, to be conducted with a view of correcting the tables on strength of materials.

[*Adjourned.*] WALTER S. PARDEE, Secretary.

OBITUARY—FRANKLIN COOK, LATE MEMBER OF THE ENGINEERS' CLUB OF MINNESOTA.

Whereas, It has pleased the Supreme Power to take from us our friend and associate Franklin Cook, a man endeared to his fellow men by his courteous and gentlemanly bearing, his integrity, his honorable life, his manliness, and his uprightness of conduct ; and,

Whereas, We feel that we have sustained a loss which our profession cannot replace to us, the loss of one who to all was an honest friend and true counsellor, a faithful adviser, and one whose memory shall not be forgotten in the coming years, when we seek the counsel and advice of others in our profession ; and,

Whereas, Our grief over the loss of one to whom no honest appeal was ever vainly made can only serve to remind us still more of the loss of a dear friend and honored associate ; therefore,

Resolved, That we, the Members of the Engineers' Club of Minnesota, do, with humbled hearts, bow to the dictates of that Supreme Will which, in its wisdom, has taken from us a friend and Member whom we all delighted to honor, and whose friendship was a source of profit to all who in daily life had need of him in private or professional business ; and be it further

Resolved, That we do hereby extend to his bereaved family our warm sympathy in this their hour of trial, and assure them of our kindest thoughts and wishes that their future shall know no other sorrow, and the darkness of the clouds that now shadow their home may be brightened by the thought that their loved one has only gone before to make more bright and happy the reunion of loved and loving ones beyond the grave.

Resolved, Further, that a copy of these resolutions be suitably prepared and presented to the family of our late associate. Signed,

GEO. W. COOLEY,
W. D. VAN DUZEE, Committee.
ANDREW RINKER.

ENGINEERS' CLUB OF KANSAS CITY.

JUNE 6, 1887:—Regular meeting, Mr. Octave Chanute in the chair. Those present were: Messrs. O. Chanute, E. W. Grant, C. M. Duncan, R. C. Simons, O. Sonne, G. W. Pearsons, C. E. Taylor, J. A. L. Waddell, A. J. Mason, Wm. Norris, B. L. Marsteller, R. C. Pearsons, Kenneth Allen and two visitors.

Record of previous meeting read and approved.

Ballots counted and the following elected:

For Member: George P. N. Sadler, Principal Assistant Engineer Missouri Valley Bridge and Iron Works, Leavenworth, Kan.

For Associate Members: Clarence A. Burton, Assistant Engineer Kansas City Cable Railway Company, Kansas City, Mo.; Charles G. Wade, Assistant Engineer Kansas City Cable Railway Company, Kansas City, Mo. Twenty-two ballots cast.

A letter from Mr. George R. Bauens, resigning his position as Member, was read and accepted.

A letter from John C. Eisenmann, Secretary of the Executive Board of the Council of Engineering Societies on National Public Works, was read, soliciting co-operation of the Club, but action in regard to it was deferred.

Mr. J. A. L. Waddell presented, for Mr. John C. Trautwine, Jr., a copy of the last edition of Trautwine's Pocket Book. On motion of G. W. Pearsons, it was voted to extend thanks of the Club to Mr. Trautwine for his gift.

On motion of Mr. Waddell, it was voted to devote the next regular meeting of the Club to a discussion of the 24-Hour System.

On motion of Mr. Mason it was voted to ask Mr. H. C. Pearsons to read a paper before the Club on the above subject at the next regular meeting.

The paper of the evening was then read by Mr. A. J. Mason—Railroad Engineering in Australia. The characteristic features of the country, and their influence, as well as that of the government, on the location and construction of railroad lines was considered, and the opening for American engineers suggested. The paper was well discussed.

[*Adjourned.*] KENNETH ALLEN, Secretary.

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COUNCIL OF ENGINEERING SOCIETIES.

OFFICIAL MINUTES OF A MEETING OF THE EXECUTIVE BOARD.

CLEVELAND, O., June 20, 1887:—Meeting called to order by President Cooley at 10 A. M.

Present, Messrs. L. E. Cooley, E. L. Corthell (vice L. M. Haupt), Augustus Kurth and John Eisenmann. Absent, Messrs. Louis J. Barbot, J. B. Davis and R. E. McMath.

The following business was transacted.

At the request of Professor Haupt and the Engineer's Club of Philadelphia, the name of E. L. Corthell was substituted for that of Professor Haupt.

The resignation of R. E. McMath was read and accepted, and Chas. F. Loweth, of St. Paul, was elected to fill the vacancy.

Mr. Loweth was appointed to take charge of the Committee of Public Works in Great Britain and Canada.

The Committee "to collect and digest all information on Public Works Systems, etc.," was reorganized and constituted as follows: Messrs. Cooley, Corthell and Eisenmann.

The Secretary was authorized to expend, not to exceed $200, to secure assistance in the compilation of reports.

A vote of thanks was passed to the Board of Managers of the Association of

Engineering Societies for privilege of publication of proceedings of the Council of Engineering Societies, and their proposition accepted.

The Secretary and Treasurer read the following report:

Bills payable on March 30th, 1886	$266.58
Liabilities incurred up to June 20th, 1887, for stationery, printing, postage and expressage	141.20
Total indebtedness	$407.78
Cash received from various sources up to date, including Civil Engineers' Club of Cleveland; Cornell University Association of Civil Engineers; Engineers' Club of Philadelphia; Engineers' Club of St. Louis; Iowa Society of Civil Engineers; Ohio Society of Surveyors and Civil Engineers; Technischer Verein of New York, and the Technischer Verein of Chicago	402.40
Balance less cash in treasury	$5.38

In addition to the above the Secretary and Treasurer is advised that several other societies have collected amounts aggregating about $130, which are at the disposal of the Board.

Beport approved and placed on file, and the Secretary was instructed to cancel all outstanding liabilities as fast as bills were presented, and report disbursements at the next meeting.

Reports of sub-committees, Barbot, Haupt and Kurth, were received, and committees thanked for their labors, and reports referred to the General Committee. It was resolved that the reports of all the sub-committees be referred to the General Committee for final digestion and compilation, the results of their labors to be presented at a meeting of the Executive Board, to be held in the Fall for final consideration, and such action as may then seem expedient.

The following named past delegates and engineers were declared Associate Members:

Archibald, James, Chief Engineer D. L. & W. R. R., Scranton, Pa.

Bergen, Van Brunt, First Assistant Engineer Board of City Works, Brooklyn, N. Y.

Budell, Max C., Germania Life Insurance Co., New York.

Barnes, O. W., Aqueduct Commission, New York City.

Chaplin, Prof. Winfield S., 16 Prescott street, Boston, Mass.

Douglass, Col. H. T., Chief Engineer B. & O. R. R., Baltimore, Md.

Francis, James B., Consulting Engineer, Locks and Canals, Lowell, Mass.

Field, Geo. S., Union Bridge Co., No. 1 Broadway, New York.

Gospel, Paul, Stewart Building, New York.

Grey, Samuel M., City Engineer, Providence, R. I.

Hausner, E. L., Cor. Beach and Taylor streets, Chicago, Ill.

Hardaway. Prof. R. E., Tuscaloosa, Miss.

Kandeler, C. F. T., 215 Ohio street, Chicago, Ill.

Murphy, Howard, 523 Chestnut street, Philadelphia, Pa.

Merriweather, Niles, City Engineer, Memphis, Tenn.

Marx, Prof. C. D., Cornell University, Ithaca, N. Y.

Nelles, Geo. T., City Engineer, Leavenworth, Kan.

Noble, Alfred, High Bridge, New York.

Potter, A. S., Omaha, Nebraska.

Sweet, Elnathan, State Engineer New York, Albany.

Smith, Frederick, Baltimore, Md.

Smith, Gen. W. F., New York City.

Swan, Chas. S., Boston, Mass.

Van Buren, Robert, Chief Engineer Board of City Works, Brooklyn, N. Y.

Williams, Benezette, 171 La Salle street, Chicago, Ill.

Williams, J. J., Jackson, Tenn.

Whittemore, D. J., Chief Engineer Mil. & St. Paul R. R., Milwaukee, Wis.

Wright, A. W., Chicago, Ill.

Wilson, John M., Philadelphia, Pa.

The Board adjourned at 4 P. M., after continuous session, subject to call of the President.

ADDRESS FROM THE EXECUTIVE BOARD OF THE COUNCIL OF ENGINEERING SOCIETIES.

The Executive Board finds such a growing sentiment in favor of a broad and general consideration of the question of the policy to be pursued toward the public works of the country, both in the legislative and executive features, that it feels renewed encouragement in continuing its labors.

The various societies are expected to continue their committees, and be ready to consider any matter that may be laid before them; meantime any work which these committees can do, or any suggestions and results which they may lay before the Executive Board, will promote the general objects of this organization.

A cordial invitation is extended to all societies, not now represented in the Council, to appoint Committees on National Public Works. The Secretary will publish all necessary information.

Signed, L. E. COOLEY, Pres.
JOHN EISENMANN, Sec. and Treas.

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. VI. August, 1887. No. 8.

JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

Corrigendum to Volume VI., page 265, line 16 from bottom:

for 28 degrees read 82 degrees.

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There can be little doubt but that the material for the whole length of the tunnel will be rock; but a portion, say from 10 to 40 per cent., may possibly require lining.

Two small valleys meet about 500 feet from the south portal and about 125 feet above grade; down one of which flows a stream which may, perhaps, supply five or six cubic feet of water per minute. The grades are arranged, however, to make the tunnel self draining, and hence no serious trouble is apprehended from that source.

The problem now is, how is this tunnel to be built to insure its completion in fourteen months.

In case much longer time is required, it will be necessary to construct an overhead line with a four per cent. grade, at a cost of $40,000 to $50,000. Experience in the Mullan and Bozeman tunnels in this vicinity,

The Board adjourned at 4 P. M., after continuous session, subject to call of the President.

ADDRESS FROM THE EXECUTIVE BOARD OF THE COUNCIL OF ENGINEERING SOCIETIES.

The Executive Board finds such a growing sentiment in favor of a broad and general consideration of the question of the policy to be pursued toward the public works of the country, both in the legislative and executive features, that it feels renewed encouragement in continuing its labors.

The various societies are expected to continue their committees, and be ready to consider any matter that may be laid before them; meantime any work which these committees can do, or any suggestions and results which they may lay before the Executive Board, will promote the general objects of this organization.

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This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

TUNNELING IN MONTANA.

BY J. T. DODGE, MEMBER OF THE WESTERN SOCIETY OF ENGINEERS.

[Read April 5, 1887.]

The route of the Montana Central Railway, between Helena and Butte, crosses the divide between the valleys of the Prickly Pear and the Boulder, at an altitude of about 5.450 feet, the surface being about 6,200 feet above the sea. This will require a tunnel about 6,170 feet in length. As in all such cases, it is of great importance to build it in the shortest possible time.

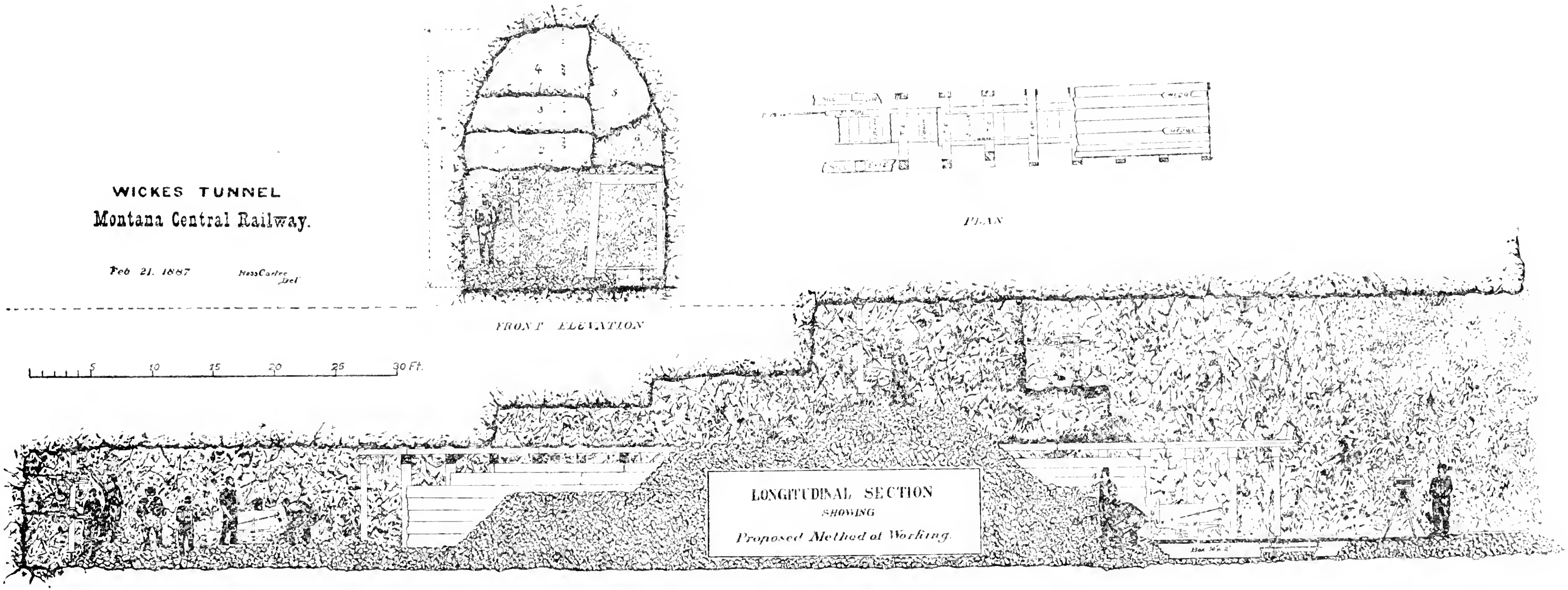
The outcroppings of rock in the immediate vicinity of the south portal are granite, and the numerous excavations made near by indicate that at a depth of 25 feet to 40 feet the rock will be self-supporting. The mountain is entirely covered with grass, and devoid of timber. The surface is smoothly rounded and shows some small outcroppings of trap rock on the slightly elevated peaks. Some veins of low-grade lead and silver ore have been found near by and appear to cross the railroad line nearly at right angles.

There can be little doubt but that the material for the whole length of the tunnel will be rock; but a portion, say from 10 to 40 per cent., may possibly require lining.

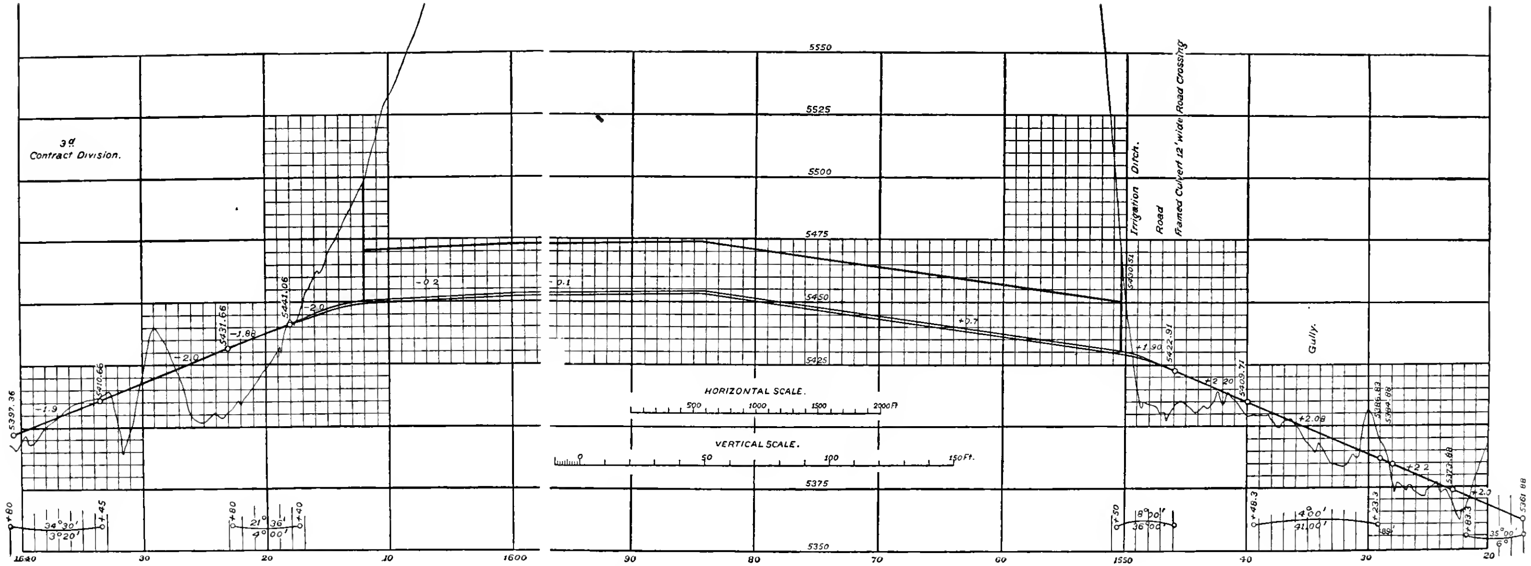
Two small valleys meet about 500 feet from the south portal and about 125 feet above grade; down one of which flows a stream which may, perhaps, supply five or six cubic feet of water per minute. The grades are arranged, however, to make the tunnel self draining, and hence no serious trouble is apprehended from that source.

The problem now is, how is this tunnel to be built to insure its completion in fourteen months.

In case much longer time is required, it will be necessary to construct an overhead line with a four per cent. grade, at a cost of $40,000 to $50,000. Experience in the Mullan and Bozeman tunnels in this vicinity,


WICKES TUNNEL
Montana Central Railway.
Feb 21. 1887
Ross Carter Del
FRONT ELEVATION
PLAN
5
10
15
20
25
30 Ft.
LONGITUDINAL SECTION
SHOWING
Proposed Method of Working.

With the Journal of the Association of Engineering Societies, August, 1887.



WICKES TUNNEL, MONTANA CENTRAL RAILWAY.

hows that it is very difficult to drive a full-size, single track tunnel, with ample machinery and high explosives in good ground, more than 7 feet per day for a series of months. To drive a tunnel at that speed requires about 75 yards of rock to be broken and shoveled per day. Nearly that amount was handled at the Bozeman tunnel for three consecutive months. By recent reports of the Croton Aqueduct, it would seem that about 80 cubic yards of rock have been broken and shoveled there per day under the stimulus of a prize. Experience at the Arlberg tunnel shows that a heading, 8 feet high by 9 feet wide, can be driven, in good ground, an average of over 17 feet per day for a year together, and that in ground where almost constant timbering was required the worst progress made, for a year together, was 3,466 feet, or 9.5 feet per day. The highest day's progress on record there was 26 feet, which would require about 75 cubic yards of rock to be broken and shoveled, in a space 9 feet wide, while a progress of 17 feet would require about 50 cubic yards.

Now, if 75 cubic yards of rock have been broken and shoveled at a face 9 feet wide, it would seem quite practicable to break and shovel a like amount at a face 16 feet wide.

When Mullan tunnel, which was entirely in granite of which 60 per cent. was so hard as to be self-supporting, was driven at the rate of 4½ feet per day, exact observations made for seven days showed that three Eclipse drills, 3½-inch cylinders, did not run over one-third the time. When the same tunnel was driven 7 feet per day the same drills were amply sufficient for the work, and though no exact records were kept in the latter case, it is highly improbable that they ran much more than half the time, and there is little doubt that they would have been sufficient to break 75 yards in a heading 8 feet by 16 feet, which would give an advance of over 14 feet per day. If now it is conceded that a heading can be driven 14 feet per day, the next question is, can the enlargement be made to keep pace with it? Experience at the Arlberg answers this question in the affirmative, not only in good ground but in bad. The same methods ought to give a like result. The question, however, is raised whether, in good ground, a simple method may not be more economical and equally efficient.

The accompanying diagram shows an arrangement for driving a heading of the full width of the tunnel and of a convenient height, say 8 feet, laying the track close to one side, with a ventilating duct, a compressed air pipe and a water pipe, directly below the track and all protected by a substantial timbering and lagging, sufficiently strong to withstand the pressure of the rock to be stoped down from above.

The number of working points for enlargement can be increased at pleasure. The only waste of labor or material required is in keeping up the timber protection of the main track, but that timber can be used over and over. Faith in a bottom heading was the foundation of the triumphant success achieved at the Arlberg, and the query is respectfully propounded to this Society, whether there is not good grounds for hoping that in these United States we may yet approximate, more nearly than has yet been done, to the achievements in tunneling of our brethren across the Atlantic.

DRAINING AND FILLING WATER MAINS.

By S. Bent Russell, Member Engineers' Club of St. Louis.

(Read April 6, 1887.)

Whenever a water main is extended or a new main laid connecting with the pipes already in service, it becomes necessary to empty the old main. In case of repairs, also, it often is necessary to draw off the water. In large and growing cities these cases are of such frequent occurrence as to demand due consideration in planning the water-pipe system and its extensions.

During the past year, for example, there were 621 "shut offs" made in this city* for various purposes.

Large mains can generally be spared from service but a few hours at most, and that only at considerable risk. In such cases it is of the greatest importance that we make such arrangement as to permit us, without fear of accident or delay, to drain the pipes, make the required connection or repairs and fill the pipes again ready for service in the shortest possible time.

That this may be done, the first requisite is a dry point of operations. A small stream of water from a leaky stop-valve will greatly delay the work, necessitating more or less men constantly at the hand pump or baling buckets, and perhaps causing caving in of the trench banks or blowing hot lead out of the joints with the steam produced. Even tight valves will not be satisfying if we have to wait while the pipe is being pumped out before commencing the work proper, and then proceed with setting the pipes or castings in a hole lined with soft and sticky mud ankle deep. The pipe should, whenever possible, be emptied at some point removed from the locus of the desired repairs or connection.

The best arrangement for discharging the water from the main is a blow-off valve at each low point in the main emptying into a sewer below.

It may be well to say in passing that the blow-off pipe should be so arranged that the stream of water from it can be seen and thus leaks may be detected and the condition of the stop valves during a "shut-off" may be observed. It may also be remarked that a blow-off valve should be of the best possible construction for durability and tightness, so that after being left without opening for twenty years it will work as perfectly as when new.†

Where sewers are not available, if the streets have sufficient fall to them, a large part of the water in a "shut off" may be discharged at the street surface. Where this is done, when it becomes necessary to drain the whole "shut off" the adjoining "shut off" below must be made, and the water drained off through that.

This is the method used in St. Louis for 15-inch and smaller pipes and sometimes for large mains. Fire-plugs make the most convenient blow-

* St. Louis.

† In a recent case of the writer's, after all stop valves were shut, the twelve-inch blow-off valve could not be opened and the adjoining "shut-off" had to be made. The whole "shut-off" necessary was thus about 10,000 feet of 36 inch pipe.

offs at the street surface, and in a city like this where most of the streets have a good fall and where the pipes form such a network that large areas of the system could if necessary be emptied at one point, if a little care be taken in locating connections, valves and fire-plugs, blow-off valves may, except at a few points, be dispensed with.

Even with a blow off at every low point in our shut off, however, al will not be satisfactory if we have to "cut out" the pipe between a blow off and a leaky stop valve. The eccentricity and perversity of stop valves are qualities more questioned by the experienced. A valve will one day leak a stream that defies hand pumps, and the next week, perhaps, shut bottle tight. One must be cautious, too, about forcing them, as a broken valve might be disastrous. To have absolute safety from water at the point of connection or repairs, we must have a blow off on each side of said point. Perhaps the happiest arrangement for the draining of a large and important main would be to have the main valves set at low points with a blow off on each side of each valve.

As to size of blow-off valves, in this city 12-inch valves are generally used for 30 and 36-inch mains and 6-inch valves for 20, 15, and 12-inch mains for the sake of uniformity in castings.

What annoyance may arise from want of proper draining facilities, the following case will show:

There is a low point on the 30-inch pipe line on Cass avenue, west of Broadway, in St. Louis, which is not provided with any blow off, so that about ten blocks of the pipe cannot be drained. Last December an old patch on a transverse crack in this pipe gave way. There was about 4 feet head of water on the crack, and no way to drain it off without cutting out. It took about 48 hours work to make a split sleeve tight over the crack, which, could the water have been drawn off, should have been done inside of 5 hours. In fact, had the job been duly appreciated, a blow-off valve would have been cut in at the start. Such a delay as this omission caused would be very alarming with a very important shut off.

Opening a blow-off valve is not all that is necessary for a quick emptying of a "shut off." Air must be admitted at some point and displace the water to be discharged.

This brings us to the principal subject of this paper, air cocks or air taps.

The air cock must serve a double duty. It must give vent to air when required, and admit air when the main is to be drained. We will first consider the air cock as used for admission of air during draining.

Let us assume a 6-inch blow off which would discharge under an average head of 80 feet were air admitted freely. Assume a 2-inch air cock at the highest point in the main. If 10 feet of our head be used to force air through the cock, sufficient air would enter to displace about 13 cubic feet of water per second. The remaining 70 feet of head would discharge about 13 cubic feet of water per second through the blow off. If our main be 20 inches in diameter it will drain at the rate of about 6 feet per second, or a mile of pipe would be drained in less than a quarter of an hour. This is a very rough approximation, of course, as it would be difficult to even approximate closely without very complete data.

To get a concrete idea of the rate of inflow of air, assume the air in the pipe to be at two-thirds atmospheric pressure. Using the formula given by Rankine for flow of air through an orifice, and the constants taken from Weisbach, we get the approximate quantity of water which would be displaced for different size air cocks:

½ inch cock	¾ cubic foot per second
1 inch cock	3 cubic feet per second
2 inch cock	13 cubic feet per second

From this we may see at a glance that whenever one can easily spare 10 feet of head to furnish air, a 2-inch cock is large enough for a 6-inch blow off, and other sizes may be roughly tested in the same way.

In considering the inflow of air, we must remember that the water is *displaced by rarified* air, so that *as we decrease the pressure* in our draining pipe we not only *increase the weight of air flowing in per second through a given opening, but we also increase the volume of water which a pound of air will displace.*

This relation of volumes should be clearly pictured in the mind before pursuing the subject further, as it is of striking importance in the problems before us.

We shall see a little further on that as a larger air cock is required for the necessities of filling than for those of draining, we must let the former determine its size.

When there are two or more low points in a shut off, and hence more than one blow off, one of them, the highest, will sometimes act as an air inlet, if there be no air cock. In one case under the writers' notice, a 12-inch blow off was observed to be drawing air for about an hour on account of insufficient air openings, whereas had there been an air inlet of the proper size at the summit, the blow-off would have been doing its proper duty, and the main would have been drained in much less time.

We have now successfully emptied our pipe, broken out and made the connection, and are ready to fill. In filling lies the danger of accident as well as that of delay.

When a water faucet which has been unused for some hours is opened, a quite startling fizz-bang often follows. The phenomenon may be explained thus:—by opening the cock slowly a small opening is made, large enough to let the compressed air, which has collected in the upper part of the pipe, escape at a great velocity. The water of course follows it up with nearly equal velocity to the opening, only to find the hole too small for escape. The velocity of the water is instantly checked, causing a shock or "ram."

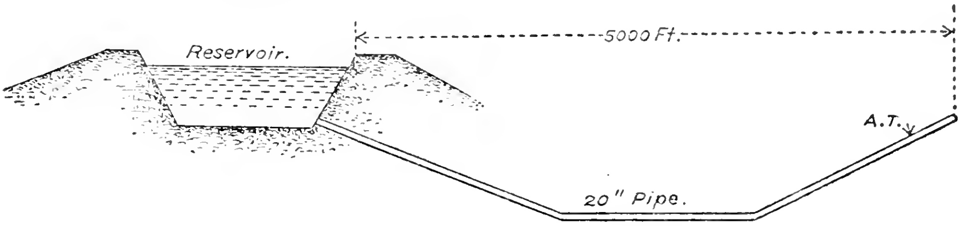
A simple formula for water ram in pipes has not yet been published in English engineering literature. Many experiments have been made and published, but they appear to know no law. The factors of the problem seem too numerous and too hard to obtain, or what is worse, difficult to eliminate.

One occasionally hears water-works men speak of "doubling the pressure to allow for ram."* Evidently they are considering the ram as a sudden load. A glance at the problem shows that the static pressure is a very small factor in the value of the hydraulic ram.

*See Proc. 6th An. Meeting Am. W. W. Ass'n, p. 101.

Mr. Fanning makes an assumption as to the time during which the energy is expended, in estimating the ram. Such an assumption, of course, renders the results valueless except for comparison.

In order to have some conception of the force of a water ram we will look over the following case.



Let us assume the above, supposing there to be about one hundred cubic feet of compressed air in the end of our 20-inch pipe, at a static pressure of 53 pounds per square inch. Now open the 2-inch air cock "A T." The pressure of the confined air will fall about 8 pounds, due to the friction of the moving water, and we will have the air flowing from the 2-inch orifice at a pressure of 45 pounds. About 8 cubic feet per second will be discharged, as shown by our formula,* and the velocity of water in our main will hence be about 4 feet per second. Now our main will hold about 10,000 cubic feet of water, or about 650,000 pounds. We have then a moving energy of 325 tons at a velocity of 4 feet per second, which is equal to the energy of 81 tons, after falling 1 foot. Let us suppose that while things are in this condition the air cock is suddenly closed. We will assume that only 30 cubic feet of air remain in the pipe at this instant, and that our pipe is rigid and inelastic, and therefore the whole energy of the moving body must be transferred to this compressed air, which acts as a cushion. Assuming that the product of the pressure and volume is constant, and solving graphically by an imaginary indicator diagram, we find that when 81 foot-tons of work have been done by the kinetic energy of the water in compressing the air, the final pressure will be about 200 pounds per square inch, and the volume will be reduced to about 8 cubic feet.†

Let us suppose that instead of the air cock being suddenly shut that the cock were at such a distance from and below the end of the pipe that when the rising water reaches and covers the orifice, about 30 cubic feet of air remain in the end of the main.

We would have nearly the same result as before, the only difference being the relief afforded by the 2-inch orifice for the escape of water. Had less air been left in the pipe the final pressure would be greater. This latter case must often occur in filling mains. The water is admitted too rapidly, so that the air in the main is under high pressure, the air cock is large enough to allow air to escape in large quantities per second, but

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* Rankine's.

† NOTE.—The pressure due the height of water in the reservoir added to the atmospheric pressure acting through the twenty-two cubic feet will perform additional work so that the total work done in compressing the air will be over 180 foot-tons.

$$\frac{144\left(\frac{45+53}{2}+15\right)}{2{,}000} \times 22 = 101.$$

is too small to give relief to the water when the air has escaped, and often there is no air cushion left to ease the blow.*

Air cocks are usually put in at high points in the mains so that air accumulating in service may be released to prevent obstruction of water way. Their use while filling the main is but incidental, and probably is not usually considered in designing the work. It may be thought by many that the cost of preparing a main for draining and filling, which are done only at long intervals, is too great for the advantages gained by such preparation; they may prefer to take the risks of damage and save the outlay. It is just as well, however, to know the factors of the problem before a decision is made.

The case of outflow of air from a filling pipe is in contrast with that of the inflow in this: as we *increase the pressure* of the confined air we *increase the number of pounds of air discharged per second, but we also decrease the volume which a pound of confined air will occupy* in our pipe. Hence, *with a given size air cock the rate of inflow of water will be nearly the same* when the confined air is at a pressure of five atmospheres as at two.

If we assume the absolute pressure of the confined air which is being displaced in filling to be two atmospheres, and that said air is escaping from a 3-inch orifice, we find by our formula † that about 24 cubic feet of the confined air will be displaced by the inflowing water in one second, This would give a velocity of about 3½ feet per second in a 36 inch main or fill *at the rate of* a mile of pipe in about 25 minutes. We see then that a 3-inch tap would be large enough to fill the pipe within a reasonable time. A dangerously heavy ram would probably follow, however, when all the air had escaped.

A smaller tap would be no better unless it be so small that the velocity of the inflowing water is very low. This would increase the delay and loss of service, and a small air cock has the disadvantage of giving no relief to the ram. Delay at this point is annoying, as filling the pipe most often comes at night, perhaps long after dark, and it is not safe to dismiss the workmen until the full pressure is on to test the new work.

A better way would be to make the air cock larger, large enough to relieve the ram or to keep it within safe limits, and regulate the velocity of inflow at the filling valve. An absolutely safe size for an air cock could be found as follows :

Let Q = greatest quantity of water which could be obtained in one minute at the air cock were air cock as large as the main and all valves to be used in filling full open.

P = maximum pressure which the pipe will safely stand.

q = quantity of water which the air cock will discharge in one minute with a head equal to P.

If q is made equal to or greater than Q, no damage can be done in filling.

In small mains and in districts where the available supply of water is

* Large air cushions for this purpose are not altogether desirable for two reasons: 1st. They are too apt to increase the damage done in case of a leak or break by their explosive action. 2d. They bring more uncertainty into our calculations.

† Rankine's.

not great, this safe method may be used to great advantage, even with all available valves full open for filling. The pipe is then filled in the least possible time.

Assuming P equal to 100 pounds per square inch and letting d equal diameter of air cock in inches, the following table gives the value of q in gallons per minute for different size air cocks :

d	q	d	q	d	q
1	245	2	980	3 in. fire-plug*	2,030
1¼	285	2½	1,530	4 in. fire-plug*	3,600±
1½	550	....	....	....	....

* Fire-plug having one 3 inch nozzle or one 4-inch nozzle respectively.

To show how this works out, the proper size of air cocks for several summits in the St. Louis pipe system has been determined in this way and is shown in the table below. The available quantity of water Q was deduced from actual observations of jets from fire-plug nozzles,* and all valves were full open.

Location of Air Cock.		Diameter of pipe in inches.	Q.	Proper size of air cock in inches.	q.
Lindell.	Taylor	12	1,450	2½	1,530
"	Kings Highway	12	1,500	2½	1,530
Prairie	Hutchinson	12	500	1½	550
Cherokee	Nebraska	12	900	2	980
Nat Br. Rd	Newstead	12	1,800	3	2,030
Twentieth	Cottage	6	600	2	980
"	Obear	6	1,150	2½	1,530
Sullivan.	Twenty-third	6	1,600	2½	1,530
Taylor	Moffitt	6	300	1¼	380
Easton	Kings Highway	6	300	1¼	380
Finny.	Pendleton	6	500	2	980
Page	Prairie	.....	1,000 to 1,500	2½	1,530
†Laclede	Jefferson	15	1,400	2½ to 3	....
†Broadway	Osceola	20	1,650	3	2,030
† "	Osage	20	1,600	3	2,030

The observation for Page and Prairie was made on the 6-inch pipes at that point intended to be used in filling the 20-inch main which has since been laid on Page avenue.

When the proper size air cock becomes inconveniently large, two or more may be used. It is not necessary that all of these be at the summit of the pipe, provided that all are kept open until all the air has escaped that will. A fire-plug 500 feet from the summit is often

* See "A System of Pipes for Furnishing Water to Fire-Engines," JOURNAL, Vol. V., No 8.

† The method of obtaining Q is hardly reliable for these large pipes.

N. B.—As this method referred to of determining available quantity of water at a poin in a system of pipes is more reliable for determining the minimum quantity than t maximum, it should be used with caution in this case.

used to help discharge the air and relieve the ram. In this city endeavor is made to so arrange the location of valves and fire-plugs that the latter may be used as air cocks in filling. The fire-plug properly located is the safest, most convenient and economical air cock.

As large air cocks might be inconvenient for letting out small accumulations of air at summits during service, it would seem better to have at least two cocks at each summit in which air might accumulate, one being large for relief in filling, the other so small as to prevent a high velocity in the main to let out air accumulated in service. The latter would not be needed in every shut off, as where the pipe system is a complete network the air accumulates in service only at the *summits of the system.*

In this city it is often necessary to make the shut off above the one to be operated upon in order to reach suitably located air inlets and outlets.

In one case last year (1886) a 20-inch main was shut off and drained to make an air inlet from a 36-six inch shut off, and when the work was completed the 20-inch was shut off again, to be used as an air outlet when filling.

When we have reached the limit of size and number of air cocks for relief, it becomes necessary to reduce our quantity Q so as to maintain the safe relation. This part of the science is usually left to the mechanics who work the valves. Too much dependence should not be placed on their judgment. If practicable, the main should be so connected that it cannot be filled but one way. If not, it might be well to set apart certain valves to be used in filling a certain shut off, and have it well understood that no others are to be opened until all air has blown off.

Large mains without side connections are usually filled through a "by-pass." The by-pass should be of such size as to fill the main at a proper velocity.* Where a main has small side connections, the neighboring pipes are generally used as a by-pass. This is saving in outlay, but has some disadvantages, such as filling the main from an undesirable point, filling too fast, taking the pressure off the neighboring pipes.

Water should always be admitted at the lowest point in the shut off if possible, especially in small mains. Water admitted at top seems to interfere with the escape of air and cause disturbance in the pipe. It often also cuts off the air-cock and confines the air until pressure accumulates, thus losing time in filling.

The location of the main valves is a factor in the convenience of filling. The most satisfactory arrangement of a pipe line for filling would be with a stop valve on each summit, having a large air cock on each side of it, and a stop valve at each depression, with a small by-pass around it. Such completeness, however, would seldom harmonize with other requirements.

It often happens that a main must be filled from the highest point, thus almost necessarily interfering with the escape of air. About the only rule for this case is to avoid it if possible.

If a by-pass is to be used for this, however, something might be done

* A 12-inch by-pass under 75 pounds head would discharge about 265 gallons per second, or fill a 36-inch pipe at the rate of 5 feet per second.

by purposely making the by-pass so small that filling may take place without disturbance.

When a shut off is high in the middle and low at each end, it should be filled from both ends simultaneously. Sufficient air vent for the increased rate of filling should be allowed.

If such a shut off can be filled from one end only, and the air vent cannot be exactly at the summit, it should certainly be beyond the summit, that is to say, the air vent should not be between the inlet valve and the summit, as it would be cut off by the rising water and the discharge of air greatly delayed.

To sum up, every well appointed shut off should be arranged with regard to thoroughness and quickness of draining, safety and quickness of filling.

In conclusion, the provisions for the convenient draining and filling of mains may appear simple enough, as stated in this paper, but when surrounded by the varied conditions of a city pipe system, they serve to sufficiently complicate the problem.

If the requirements of draining and filling are properly kept in view in planning and extending a distribution system, greater safety will be dassure and the cost of future maintenance appreciably reduced.

STEEL TAPES.

BY JOHN L. CULLEY, MEMBER OF THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read February 22, 1887.]

The plan upon which our government lands are surveyed is undoubtedly the best ever devised for such a purpose. The land being laid off in half-mile squares, the purchaser generally obtains so many whole sections and quarter sections. The law specifically determines how lost corners shall be restored, so that whatever errors there may be in the original government survey they are confined within these comparatively narrow limits. The beauty of the system is that, the original lines being laid out north and south, and east and west, the bounds of the subsequent purchaser are, as a rule, laid off parallel to the original lines, and are, therefore, easily reproduced.

As the land increases in value, these purchases are subdivided again and again, whilst each successive subdivision is estimated by a more and more refined measurement. Finally the time comes when every precaution is taken to obtain the absolute dimensions of the land.

This process of refinement is noticeable in the field work of the better class of private surveyors of this country. Thus, the city of Cleveland was laid out from the Cuyahoga River to Wilson Ave. in 1797, by the Connecticut Land Company. This survey—remarkably consistent and well executed—has a surplus of some 0.67 to 100, which is nearly uniform throughout the whole survey. The surveyors in this vicinity, of 60 and 70 years ago, used a surplus of from 0.17 to 0.25 per 100, whilst those of 40 and 50 years ago intentionally used a surplus of 0.08 per 100. Even these refinements were far in advance of those of observed angles, which

were dependent upon the compass, whose closest reading was one-fourth of one degree.

With the introduction of the transit, reading angles to a fourth of a minute, this order was reversed. Then line measurements became the unknown quantity, whilst angle observations became a certainty.

The 66 and 100 feet chains, each of 100 links, were, of course, the standard used by the old surveyors. There were three reasons why they could not be relied upon for accurate work :

1st. The sag, due to their weight, materially shortened their length when drawn to a line above the ground ;

2d. Their lengths were constantly increasing from the strain in chaining and from the slight abrasions at each of the 600 wearing surfaces in every chain, and,

3d. They were liable to kink and shorten under the slightest provocation.

Their weight was no slight objection, especially if it came your turn to drag it over a recently thawed clay territory in the early spring. These objections were practically overcome by the advent of the tempered steel tape.

It was about 1860 that the first steel tapes were imported and used in this country. It was not until 1873 that it was used in this city for general land surveys. Now nothing else is used here for either city or farm measurements. It is rapidly being applied to all branches of engineering measurements. Nor will it be long ere the old chain with the Jacob staff will be counted with the relics of the past.

James Chesterman & Co., of Sheffield, England, are undoubtedly the largest manufacturers of steel tapes in the world. James Chesterman was the inventor of the steel tape, as well as of his processes of rolling, tempering, printing and of polishing, all of which he covered with letters patent.

Geo. M. Eddy & Co., of 351 and 353 Classon avenue, Brooklyn, N. Y., one of the largest manufacturers of tapes in this country, have been in this business since 1846, and have manufactured steel tapes since 1867. Their processes of manufacture are their own peculiar inventions, and like those of the English house, their processes are unlocked trade secrets. The distinguishing feature in the appearance of these two makes of steel tape is that, whilst the English is polished on all its faces and edges, the American is polished only on its edges and on the graduation; its other surfaces are a dull blue black. This distinction, however, disappears when the American tape has been used a short time. When new, the Eddy tape can be much more easily read than the Chesterman. Where parties use tapes sparingly this feature would be of great advantage. The expert, however, finds no trouble in reading either tape. Both are excellent tapes and well mounted, and are printed to each and every $\frac{1}{100}$ foot.

Whilst the knowledge of the more particular processes of manufacture is denied us, we are in possession of the main facts. After the rolled ribbons have been tempered and ground, in quantities of from one to two dozen at a time, they are laid upon an iron table 50 feet long, which has a standard on each side. The standards are of govern-

ment length at 62 degrees F. The ribbons placed on this table in lines parallel to the standards, are made fast at one end, and a strain of 12 pounds under a spring balance is applied at the other. They are then printed with a wash or varnish not affected by acid and then etched in a diluted nitric acid bath—the graduation being covered by the wax is left in the original surface of the tape.

The trade secrets are the results that have accrued to these enterprising manufacturers from long years of careful manipulations. I am indebted to L. Becknar, of Toledo, O., and Geo. M. Eddy & Co. for the above information.

Both of these firms are devoted exclusively to the tape trade, each manufacturing a variety of steel, as well of cloth tapes. Chesterman & Co are best known by their ⅝-inch web tape, whilst the Paine tape is the better known tape of the Eddy house, which has the advantage of a narrow web (¼ inch), offering slight resistance to the wind, and of being wound within a 4-inch reel.

All steel tapes are of the best French spring steel, capable of great strain without rupture, and of returning to their normal length when the strain is removed, and are of government standard at 62° F. Constantly using steel tapes for the last nine years. I have yet to find one that will not return to its normal length after the application of the most severe strain.

Nothing has contributed more to the general use of steel tapes than the introduction of *band chains*. The universal price of a good steel tape is $15. Band chains are sold at less than one-half the price of the old link chain. Band chains are narrow steel bands graduated into large divisions, frequently into 25 and 50 feet lengths only, but usually into 5 and 10 feet lengths, with each end foot into tenths. They are not a printed tape, hence they are called band chains, to distinguish them from steel tapes. They are not designed for the fine work to which the steel tape is adapted, but for rougher and more general work. They are thicker and narrower than steel tapes, and are therefore more adapted to their harder usage. They are admirably adapted to railroad work, and are a decided improvement upon the old chain for farm or country surveying.

Band chains are of a great variety of patterns. Although there are many excellent ones, I will now make mention only of three different makes.

1st. The *Hodgeman*, manufactured by L. Beckman, 57 Adams street, Toledo, O., from the best *polished* blue steel wire, varying from $\frac{5}{32}$ to $\frac{5}{16}$ inch wide, and from No. 30 to No. 36 gauge thick, the cross-section of a single band chain being uniform throughout its length. The standard Hodgeman is 100 feet long, of ¼-inch No. 32 gauge. Babbit metal is fused on to the band at the desired points, into which the proper figures are stamped. The price of this tape is remarkably low. A 100-foot line, graduated every 10 feet, costs $2.50; graduated every 5 feet, $3; or graduated every 10 feet and the end foot into tenths, $3.75. Handles are 50c. a pair extra. They are used extensively in the West, and are indorsed by no less authority than J. B. Davis, of the University of Michigan.

2d. The *Sager*, manufactured and sold by the inventor, Frederick J.

Sager, C. E., at Marysville, O., is of the finest spring steel, and of only one size of scant $\frac{1}{32}$ inch thick by $\frac{1}{4}$ inch wide. They are very well made and gotten up. The graduation is performed by sinking figures into small copper plates, which are swedged around and brazed to the line. This tape, 100 feet long including its large handles, costs graduated at ends only $3.25; every 10 feet, $4.25; every 5 feet, $4.75; whilst his brass reel costs $4.00. These tapes are extensively used by railroad engineers, and largely by the surveyors of this State. Mr. Sager has invented an ingenious riveting machine, for the repair of his tape.

3d. The *Roe*, by Justus Roe & Sons, Patchogue, Suffolk County, N. Y., is of fine tempered heavy spring steel, $\frac{1}{4}$ inch wide by $\frac{1}{64}$ inch thick. The graduation is made by riveting alternately, at the 5 and 10 feet points, with brass rivets, brass and copper plates, into both faces of which the figures are stamped. The 10-foot points are also designated by extra rivets in line along the band at these figure plates thus: 10 feet by 1, 20 feet by 2, 30 feet by 3, 40 feet by 4 and the centre by 5 rivets, after the manner of the old chain 10-foot tags. The Roes are the first and only makers that have successfully nickel plated steel tapes.

A 100-foot line, including reel and handles, costs $4 and $5, according as it is graduated every 10 or 5 feet, the two end feet in each case being graduated to tenths; nickel plating for a 100-foot line is $2 extra. This is undoubtedly the best band chain in the market. It costs more than either the Sager or Hodgeman, but has the advantage of a graduation made without the application of hot metal, which always weakens or destroys the web fibre. This objection is less applicable to the Sager than to the Hodgeman. The soft metal graduation of the Hodgeman is liable to wear off in practice. No band tape graduation is as permanent as that of the printed steel tapes.

The reel is the band chain's weak point. Mr. Sager has invented the only good one, but its price is too high for the trade. The band chain reel should be of good design and workmanship, capable of folding up compactly, and its cost should not exceed $1.50. A serious objection to band chains is their bulk when reeled, as their thickness prevents them being wound around a narrow coil. Band chains are not designed for thickly-populated districts, nor is it advisable to use them when the measurements require a steel tape to measure the fine divisions—a steel tape had better be used for the whole work. Band chains offer a small resistance to the wind, whilst steel tapes are finely graduated and reel into small cases. Tapes of the *Excelsior* type are unsuitable for field work Their extreme width and weight cause them to sway in the wind and sag on level lines above the ground so as to render it impossible to measure work accurately with them. The Excelsior is manufactured by Seidler Bros., Leipsic, Germany. This tape has a very poor reel.

Upon the general subject of steel tapes I would recommend:

1st. Band chains should have handles at the front end only. The rear handle fouls the chain by catching in brush, etc., and its place should be supplied by a brass ring $\frac{3}{4}$ inch in diameter.

2d. The common steel tape is too wide. Its width should be reduced to $\frac{5}{16}$ inch and its thickness increased accordingly. Its reel, however, should never exceed 5 inches diameter or loose its charming capacity of entering your coat pocket.

It might also be stated that whilst the cost of band chains is reasonably low, steel tapes are exorbitantly high. There is no good reason why a 100 feet $\frac{3}{8}$ inch steel tape of the Chesterman type should cost more than $10.

Distances can be as readily measured whether the zero or far end of a steel tape be used or its front end. If the reel end be made the forward end, the objections many engineers have against using a reel attached tape will be overcome, whilst they will have the consolation of always knowing where the reel is when needed.

The advantages of having tapes graduated beyond the zero or other initial points is outweighed by the objections against such arrangement.

The assurances of the makers to the contrary notwithstanding, every tape, whether steel tape or band chain, should be cleaned thoroughly each time used. Slight rust can be readily removed by the application of coal oil and by rubbing it with waste. Emery paper should be used only in case of deep rust, for it wears away the graduation and body of the tape. Tapes should be slightly oiled when laid away or not in use.

It is only by the use of steel tapes that the science of fine line measurement is attainable. The great sources of fluctuation in fine line tape measurements are due to three causes: 1st, Temperature; 2d, tape strain; and 3d, the greatest of all, to the methods of pin setting. To be accurately done, this last requires constant care and attention. Pins should be set under vertical plumb lines, and should measure the exact tape length from centre to centre. The second source may be eliminated by drawing the tape always under a constant pressure, and making due allowance therefor, determined from test of tape under a spring balance. The least is temperature. A change of 10° F. on a 100-foot tape will affect its length only 0.006 foot, and owing to the great variety of substances and their varying powers of heat conduction, allowances for this source should be made only for considerable range of temperatures or for long line measurements.

In this latter day revival of stadia measurements, the mistake should not be made that such measurements are ever to be regarded as certain or reliable. They are only approximations of true quantities, and are useful only as such. The gradienter is far more preferable for this purpose; it is simpler in construction, more truthful in operation and reliable in results, while its cost is much less than that of the stadia attachments.

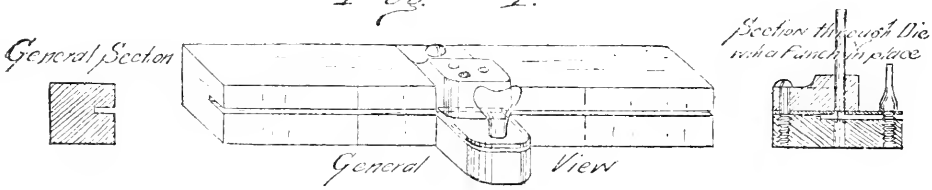
The admirable system of abbreviated field notes used by the surveyors in this locality is unexcelled for rapidity of application, or for the amount of work that can be accomplished by it in a given space of time. Only 5 letters are required to do its work. Thus $m =$ a fixed distance determined by measurement; $md =$ a given distance laid off; $ob =$ an angle determined by observation between fixed points; $t =$ a given angle turned off and $r =$ a repetition; as $mr =$ a fixed distance measured twice with the same results, etc. These letters are used immediately after the figure affected by them, thus 421·95*m*; 2307*md*; 35°—07′*obr*, etc.

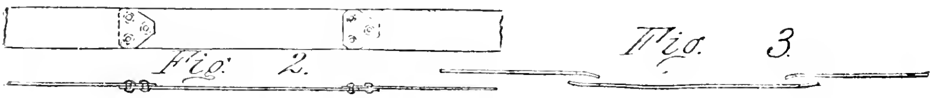
In 1882 Mr. C. H. Burgess perfected a machine for repairing broken Chesterman steel tapes. He used a capstan screw that punched three holes simultaneously. My improvement on this machine, shown below, con-

sists in the removal of the capstan and the use of a guide block in its place, through which the punches are separately applied and the holes in the tape punched from a slight hammer blow. The objection to the capstan is, that when one punch is broken the other two are useless. It is also important that the three capstan punches should have exactly the same length or lead, a condition rarely ever realized. By the arrangement shown in Fig. No. 1 you can proceed with the punching when you have broken a punch, simply by getting another one. A few extra punches only are necessary to provide against such accidents.

The guide holes and dies should be exactly in line. The two fine vertical lines on the machine face are exactly $\frac{2}{10}$ feet apart, either one being exactly $\frac{1}{10}$ feet from the centre of the 3 dies. The long slot also in the machine face is one-half the width of a steel tape. The clamp plate

Fig. 1.





is operated by a thumbscrew in the front, and is hinged in the rear by a long screw passing through it and the guide block. The centre of the tape space to be punched is placed exactly $\frac{1}{10}$ from one of the gauge lines, which is best done on a full tenth, or a 5 hundredths, line. The tape is then clamped and the holes punched. The splice may be of any length. It should, to avoid error, be an even number of full tenths of a foot, nor should it ever be less than $\frac{1}{10}$ feet. Old tapes are used for splices. The tape ends are cut off with a pair of nippers, and in cutting them the nippers should be held a little above or below the tape alignment, so that the cut ends may be bent as shown exaggerated in Fig. No. 3, and that when riveted, as in Fig. No. 2, the laps will hug one another tightly, preventing their filling with dirt, or cutting your hand as it passes along. Die punches and rivets should be of one size. Chesterman $\frac{3}{8}$-inch web requires $\frac{1}{4}$-inch No. 20 brass escutcheon pins. Repairs should never be made with solder, or other soft hot metals, for reasons already given.

Every surveyor should have a conveniently located permanent base of government standard length by which he should test his tape every time it is repaired. Such base should never be on a building floor, nor on substances affected by settlement, or such that temperature will affect the length of the base.

IMPROVEMENTS IN STEEL TAPES.

By J. D. Varney, Member of the Civil Engineers' Club of Cleveland.
[Read February 22, 1887.]

Whether or not the subject of steel tapes is interesting to you it has during the past five years interested me more than $100 worth. While quite young, I read a book entitled the "Pursuit of Knowledge under Difficulties," which related the terrible exertions of would-be wise youths to overcome obstacles in the pursuit of knowledge. The impressions left on my mind by that book are quite similar to those left by "Fox's Book of Martyrs." I lay no claim to martyrdom or anything else heroic, but I have been in pursuit of a tape under difficulties. I have here for your inspection seven tapes marked respectively No. 1, No. 2 A, No. 2 B, No. 2 C, No. 3 E, No. 4 and No. 5. The numbers relate to the class or kind of tape ; the letters to the particular tape before you.

No. 1 is the well-known Chesterman steel tape manufactured by James Chesterman & Co., of Sheffield, England. It is wound in a leather case $4\frac{1}{2}$ inches diameter, is $\frac{3}{8}$ inch wide and .015 inch thick. Probably there is no tape in the market which is better made than this. The greatest objection to it is its liability to breakage. When straight, it is sufficiently strong. It can even be wound around the hand, and subjected to any useful strain without injury, but with a short kink in it a breakage will be caused by a strain so slight as to escape the notice of the person producing the strain. In trying to avoid these breakages another defect is developed. It becomes necessary to wind it often to avoid accidents, but this case is so small that a little dirt on the tape prevents its being wound in. Besides the limited capacity of this case it is close, and holds moisture, causing rust. I will not bore you with an account of my many devices to overcome these difficulties. Let it suffice that when I saw this (No. 2) I was ready to sing "This is the tape I long have sought."

No. 2 is the Excelsior tape in a brass frame. It is one-half inch wide and varies in thickness from .007, as in No. 2 C, to .01 as in No. 2 B. There may be a wider range which I have not met with. It is manufactured by or for Keuffel & Esser, of New York. Compared with No. 1 after 3 years use I find No. 1, being lighter, requires less strain to take up the sag, and, therefore, with the same watchfulness capable of more uniform measurements. With increased care and strain, measurements with No. 2 are equally satisfactory with those by No. 1. The width alone of No. 2 would make it more liable to kink, but its greater weight and strength causes it to resist short kinks and reduces the liability to break. One hundred feet of either of them cannot be used with accuracy in a high lateral wind, and the more narrow No. 1 probably has the advantage in such a wind.

When there are bushes or other obstructions in the middle of the tape among which the tape is to be placed and straightened, No. 2 is heavy enough so that the two men at the ends can throw it into position as chain carriers soon learn to do with a chain, a feat which had nearly become a lost art, however; while in using the lighter No. 1 it must be

placed carefully in position by actually grasping the middle. This reel (No. 2) does not confine moisture, and is much more conveniently handled than the case. It is often necessary to drag this end a short distance, when this reel offers less resistance than the case. After considerable use another objection to No. 2 was developed, perhaps not important and yet annoying. Being so wide the two edges became perceptibly unequally stretched by use, developing a curvature and an actual though perhaps not a measurable inaccuracy in the length. This reel has no more spare room than No. 1, possibly not quite as much. Certainly in this I have had sufficient water adhere to the tape to prevent its being wound up.

I found to my regret and cost that No. 2 will break, though not as liable to break as No. 1, and on the whole I preferred it. Before speaking of my next move I must go back and speak of another phase of the subject.

I had with others been discussing the influence of heat and cold over the accuracy of our work. In a lecture by Professor Mendenhall, of the State University, before our State Society in January, 1884, he offered to give engineers the benefit of the very superior apparatus of that institution for testing tapes. I placed in his hands this, No. 2 A, and after due time he returned it to me with a statement, of which this is a copy.

MEASUREMENT OF STEEL TAPE, 100 FEET EXCELSIOR, BELONGING TO J. D. VARNEY, PHYSICAL LABORATORY, OHIO STATE UNIVERSITY, JANUARY, 1884.

Measurement.	Tension.	Temperature.	Length.
First............................	10 pounds.	63° F.	100.009 feet.
Second..........................	10 pounds.	64½° F.	100 013 feet.

Mean length, 100.011 at 63¾° F.

There is a constant error of .001 feet at the zero end, leaving an error of .010 to be corrected by temperature. Co-efficient of expansion × .000007 for 1° F. Temperature at which tape is correct = 49° F. Several measurements were made to test the graduation. The errors detected were too slight to require notice.

Since that time I have kept this to test others by, and for no other purpose.

You will observe that No. 2 A is a light tape compared with No. 2 B. No. 2 B. is .02 foot shorter than No. 2 A, and No. 1 is .01 foot shorter than No. 2 A. No. 2 C is a 50-foot Excelsior ½ inch × .007, still lighter, and .001 longer than one-half of No. 2 A. This difference between light and heavy tapes appears also in the Chesterman make.

Applying Prof. Mendenhall's formula, which is substantially the same as we find in the text books, and No. 2 B is correct at 78 degrees, No. 2 C at 20 degrees + and No. 1 at 63 degrees. Since writing the above I have learned that Chesterman & Co. adjust this tape (No. 1) to a temperature of 62 degrees, and as the difference for 1 degree = .0007 is a finer measurement than I pretend to make, I accept their figures as correct.

The zeros of both Nos. 1 and 2 are some part of the brass work of the end ring, an arrangement which is inconvenient, besides the inaccuracy shown by Professor Mendenhall.

My next move was to open negotiations with Keuffel & Esser for the manufacture of a tape with the following modifications of No. 2.

1. A frame with at least one inch more space in diameter.
2. The zero to be on the tape and not any part of the brass work.
3. At least $\frac{1}{10}$ foot extra beyond the 100 feet to be divided to .01 to enable me to get 100 feet in any temperature.

I only insisted that the graduations must be uniform and within a reasonable range, for in our variable climate the tape in use is probably at any other temperature between 40 degrees and 80 degrees as often as at 60 degrees. Later we decided to have the tape narrow and in time they sent me one in a reel similar to No. 3 E, differing from it only in being adapted to a tape $\frac{1}{4}$ inch wide, while these are $\frac{1}{2}$ inch wide. These reels differ from No. 2 in having a larger core on which to wind the tape, which is an improvement and necessitates a longer frame; but you will see they have not given the extra space I asked for, but as if in utter contempt of my wishes they introduced this pulley and spring, which have been detached, and which I will not attempt to describe, but which so completely occupied the little space there is as to render it very difficult to wind the tape when it came from their hands. These reels differ from No. 2 in having the crank longer. The handle is also longer, necessitating an opening through the axis to admit the handle when the crank is folded. These are great improvements over both No. 2 and No. 1.

Besides some other fatal defects in the tape they sent me, the steel of which it was made was so inferior in quality as to render it utterly useless. Later they sent me another in which some of the defects were remedied, but with no improvement in the quality of the steel. The situation was discouraging. The reel I had seen was so superior to Nos. 1 and 2 that I did not feel willing to go back to either of them, and yet to secure durability, the object for which I first started in pursuit, I must have good steel. My next move was to ask Chesterman & Co. if they would make a tape to suit me without either case or reel, my idea being to get a good tape, and then to go to some machinist and have a reel made to suit myself. In reply I received from them these samples from which to select the ribbon I would have, and a promise to try to suit me, and they also thought they could suit me with a case. The result was that Mr. J. M. Ackly and Mr. C. C. Merchant joined me in an order through Wm. Bingham & Co. for three tapes, and in due time we received them, one of which is before you marked No. 4.

It is in a sheet-iron case $6\frac{1}{2}$ inches outside diameter, handled by a leather strap on the side to go over the hand. The core is $2\frac{7}{16}$ inches diameter. The ribbon is $\frac{1}{4}$ inch wide and .015 inch thick. The zero is $2\frac{1}{2}$ inches from the ring end. There are ten .01 divisions beyond the 100 foot mark. Its length is .02 less than No. 2 A, and therefore is correct at 78 degrees. The quality of the steel seems to be fully equal to that in No. 1. I have used it but little, but believe that it will prove as durable as is consistent with convenience in use. The first use of this tape developed a weakness in the fastening of the end ring to the tape and in the screw which connects the tape to the centre of the case. Both of these, you will see, have been easily remedied at an expense, however, of 75 cents. There is in this the same lack of space, rendering it necessary to

clean the tape every time it is wound, and yet it is so large as to be inconvenient to carry in any pocket which is not well adapted to old-fashioned cooning excursions. For myself I would prefer to have a tape conveniently adapted to use without loss of time in the field, and I will provide means to transport it.

While corresponding with Chesterman & Co. I met George Hartnell, and found him using a new Excelsior tape, similar to No. 3 E. The steel appeared to be superior to the narrow ones sent me, but much inferior to Nos. 1 and 2. He seemed to be pleased with it, and, needing one, I ordered, and in due time received this No. 3 E. In accordance with my order, it differs from Mr. Hartwell's in being heavier and in having forty .01 divisions beyond the 100 feet, which I find very convenient. It is ½ inch wide by .013. I have previously described the frame. There is one curious fact about this tape. The first 50 feet are the same as each 50 feet of No. 2 A, but the last is .01 short. By using +.01 it is then correct at 49 degrees. This is a heavy tape and long, but No. 3 is a different make from Nos. 1 and 2, and I have had no opportunity to compare its length with any of a different thickness of the same make.

This tape No. 5 was sent by Chesterman & Co. with No. 4, with a request that I should try it. It is 100 feet long, divided only to feet. It has handles and is intended to be used separate from the case. By an ingenious arrangement, it can be wound in without removing the handles. I think if those who are using chains would substitute this they would find it more satisfactory in every way; but as I have no use for a tape which is not divided to .01 foot it does not interest me.

One fact developed by this experience is very unpleasant, to say the least. From the crown of my head to the bottom end of the tacks in my boot heels I believe in protection as against free trade, but the fact remains that No. 1 and No. 4 were made in Sheffield. It is true that the quality of steel and the workmanship in No. 2 is equal to either of them; but K. & E. have a branch house in Germany, and I suspect, what I do not know, that No. 2 was made the other side and No. 3 on this side of the big pond.

NATURAL GAS.

By N. B. Wood, Member of the Civil Engineers' Club of Cleveland.

[Read January 11, 1887.]

I perhaps need not explain that under this title I intend only to call your attention to that substance which is now usually known by that name, and not to the numerous other substances to which the name would be equally applicable. It has, under this name, become familiar to all, and by all deemed a matter of much importance. The future of manufacturing districts is being considered by some to hinge on the possibility or impossibility of obtaining it in large and continuous quantities. Every periodical, either scientific or otherwise, feels bound to make mention of it in some form, and it may be truthfully said that we are now in the febrile stage of a *gas craze.* But the engineer cannot afford to lose control of himself and plunge into a mad race for a bubble (even if

filled with gas). He must assure himself that there is something substantial upon which to build, and, finding that, proceed coolly to the desired end.

What are the properties of natural gas? Whence its origin? Where can it be obtained in paying and continuous quantities? How and how far can it be conveyed profitably? And of how much actual importance, economically considered, is it? are questions which naturally suggest themselves. It is perhaps not necessary to enter into a very minute description of this substance. Indeed it would be impossible to do so, except for named localities, since specimens from different places differ somewhat in density, odor and composition, and consequently in value as illuminating gas and fuel. But in general it may be said to be marsh gas (CH_4) mixed with more or less vapor of heavier hydrocarbons and sometimes with carbonic acid. Fortunately the latter is only occasionally present in quantities sufficient to seriously impair the quality. It will be readily understood from this why a high specific gravity would be no guaranty of quality, since carbonic acid would increase the weight with a corresponding decrease in its value. But in general a high specific gravity does indicate a better quality of gas; particularly for illuminating purposes. The specific gravity of marsh gas is .557 (air being unity), while the natural product varies from .519 to .693. Two samples from this neighborhood had specific gravities of .689 and .657, with no carbonic acid, while that of West Bloomfield, N. Y., has a density of .693, with 10 per cent. of carbonate acid, and Pennsylvania wells yield a gas weighing from .519 to .592, with carbonic acid ranging from traces to 3 or 4 per cent. I calculate that 19 cubic feet of our gas weigh one pound avoirdupois, while in Pittsburgh 23.5 are allowed. Pound for pound the Pittsburgh gas is the more valuable for fuel, but a foot of our gas is worth more than a foot of theirs for that purpose, while for illuminating purposes Cleveland gas has decided superiority. The explosive nature of a mixture of this gas and a proper quantity of air or oxygen, is well-known and of only too frequent occurrence. It is this which is the dreaded fire-damp of the coal mines. A mixture of one volume of gas with about ten volumes of air explodes with great violence when touched with anything at a white heat, or nearly so, but is not exploded by red-hot bodies, or even the electric spark, unless a strong one. On account of this peculiar property of this gas, Sir Humphrey Davy (or, as some say, Stevenson) found it possible to construct a lamp which, though often red-hot from the ignited gas within, does not explode the mixture without. I should advise all who use natural gas, or whose houses are near places where it is used, to use some sort of safety-lamp when it becomes necessary for them to go into their cellars, for it is impossible to tell when some leak may occur, which may fill a cellar unsuspected, and be discovered only after disastrous results. Of course this precaution would be unnecessary where the gas has a perceptible odor, such as the gas from this part of the country has, and which I presume, all heavy gas has; but the gas from near Pittsburgh either has no odor or loses it before it is delivered to the consumers. The illuminating power of this gas, even of the heavier variety, is only moderate and that of the lighter very poor. The burners in use at present seem to be unsuitable. The slightest draft

causes the light of the flame to die out and burn for some time with a bluish flame like hydrogen, hence it is not suitable for illuminating manufacturing establishments where currents of air are unavoidable.

Lately, while traveling through Colorado, I was, more than ever before, impressed by "the testimony of the rocks," with the vast periods of time which must have elapsed during the formation of the present earth's surface. Among the mountains are found petrified forests, fossil leaves, birds and fishes in formations which undoubtedly are of recent origin, comparatively speaking, but which must have existed for untold ages, yet were evidently formed since the upheaval of the mountains, belonging probably to the geological period known as Eocene, or perhaps a little later. At the base of the mountains we find the outcrop of coal, not the coal of the carbonaceous period, but the more recent cretaceous coal or lignite variety. This coal has, in places, an almost vertical position, showing it to have been upheaved, also showing it to have been a perfect formation before the upheaval of the mountains. Notwithstanding these incomprehensible periods of time which must have passed since the great disturbance occurred which formed these mountains, not the slightest appearance exists which would indicate that any decomposition or alteration had taken place in these coal deposits since that time. Below these deposits, or anterior to them, we had the formation of our carboniferous strata, our sub-carboniferous shales, thousands of feet in thickness, until after a bewildering length of time, we arrive in retrograde at the Devonian period or age of fishes, during which the Huron shales were deposited and the formation of gas in paying quantities began.

It is believed by geologists that all of this fossil or natural gas is the result of the decomposition of the organic matter contained in the Huron shales. This is only in part true, or, perhaps, not true at all. The fact is that this gas is formed whenever and wherever organic matter is subjected to the continued action of water, and under favorable circumstances, such as a temperature of 60° or more, the formation is quite rapid. So we find natural or marsh gas almost everywhere. It is one of the most universally present substances known. It rains to-day, a pool of stagnant water accumulates and to-morrow if we stir the mud at the bottom, bubbles of natural gas escape and rise to the top of the water. We find large tracts of land, which, though perfectly safe to walk upon, tremble with each step with an undulatory motion like that of water. A more or less thin stratum of soil composed almost entirely of vegetable matter floats on the surface of water in consequence of the lightness due to a large quantity of natural gas entangled in it. The gas escapes when of sufficient quantity to raise the soil above the level of the water. If such a soil could be covered with a stratum of plastic clay we should have the conditions necessary for the formation, storage and purification of the gas as they existed when our gas producing districts were being formed, the carbonic acid naturally present being carried away by a sort of exosmosis process. The "mud lumps" at the mouth of the Mississippi are no doubt due to accumulations of this gas in quantities sufficient to form small craters communicating with the organic deposits buried beneath the sand and mud brought down by the stream (see "Lisle's

Princ. of Geol.," vol. i., page 448). Mr. Whitelaw informs me, that while constructing the tunnel under the lake, to procure water for the city not contaminated by shore influences, he encountered such quantities of gas that a special conduit was put in to convey it to the mouth of the tunnel, where it was ignited and burned during the summer until the work was completed. This gas, like that at the Mississippi's mouth, probably emanates from organic matter brought down and deposited by the river, the tunnel and crib being located nearly opposite the original river's mouth. but it may come from the shales which lie only a few feet below. Gas occurs in nearly all coal workings of whatever period, particularly where the workings are deep below the surface. This is where we should have expected the greatest quantity, since the quantity of organic matter deposited must have been immense, and subjected to those conditions most favorable for gas production. But the conditions necessary for its storage were wanting, and it escaped much the same as it does from our peat beds and quaking bogs at present.

It is evident then, that no particular geological period monopolized the gas producing process. Every age after the Azoic tried its hand at it, but most of them wasted the precious fuel almost as fast as it was formed, so that the great source from which we must obtain it is the Huron shale, which immense deposit of vegetable and animal matter was deposited deep down in the Devonian sea, with sufficient clay mud to make it impervious to gas or water, several hundred feet in thickness. The gas formed immediately (geologically speaking), the same as it would to-day if similarly deposited, and the clay prevented its escape.*

Ages upon ages probably elapsed before this condition of things was disturbed. The clay indurated into shale holding the brownish organic matter as an unchanging component part—convulsions of nature took place which in these regions were comparatively slight, but further south and east were very violent, so that while here the rocks lie nearly level, there they were rent and tumbled about, forming hilly and mountainous country. Probably these disturbances took place under water, else the gas would have escaped. Aside from these disturbances other factors of a physical and geological nature must enter into the problem of accounting for the immense quantities of gas met with in the southeastern part of Ohio and western parts of New York, Pennsylvania and Virginia. There a more porous rock favorable to the transmission of fluids exists. There, also, has been internal heat, which has, in all probability, expelled by destructive distillation the volatile portions of the deposit. Of thi we have proof in the anthracite coal, the distilled products of which may possibly have been added to those from below. This influence alone would tend, under favorable conditions for storage, to immeasurably increase the quantity to be obtained, and would probably affect the quality. Oil and gas would be simultaneously disengaged in quantities varying with the intensity of the heat and in quality regulated likewise.

In an experiment, made to determine whether heat is playing or ha

* Note.—Prof. Morley criticised this by saying that the formation of gas would be much slower than the phraseology of the paper would indicate. The formation of gas would go on *slowly* for a *long* time, and is *perhaps* being formed slowly, *very slowly* now, he thinks.

played an important part in the production of gas, I subjected some of the shale borings of a well, then, at the depth of 1,150 feet, to the following experiments. A small glass retort filled with 300 grains of the previously dried and pulverized shale was subjected to a gradually increasing heat until the thermometer registered 510°Fah. No gas or other volatile matter, except one grain of water, were noticed. One thousand grains of the same were then put into an iron retort and exposed to a very gradually increasing heat in a muffle, the products of distillation being passed through a tube immersed in a freezing mixture to insure condensation. The first distillate was water; then water mixed with a nearly colorless oil, the heat being still below red visible in the dark; at a red heat just visible much water still distilled, accompanied by oil of a yellow color and gas, the odor of which was almost unbearable and clearly indicated its animal origin. The result of the experiment in tabular form would be thus:

Water (per cent.)	4.25
Oil (per cent.)	1.25
Gas (per cent.)	4.75
Total volatile	10.25
Residual carbon	6.40
Total organic	12.30

It would seem from this experiment that the oil is possibly already formed and not the product of destructive distillation; but that has not yet been determined. But it is evident that neither gas nor oil are being formed at the present time by the aid of heat, nor does it seem probable that they ever were formed in that manner in this part of the country. The temperature in all gas wells, and mains conveying it underground, both here and in Pennsylvania, as far as I can learn, is about 45° Fah, We are therefore forced to conclude that no gas is now being formed, except in very recent deposits, and that no gas has been formed in the strata on which we depend for our supply, for perhaps millions of years, since we cannot conceive of organic remains such as we find deposited there undergoing any further decomposition, or of resisting the ordinary tendency to decay for more than a few centuries at most. Still, like in a great many other geological problems, no matter which way we turn, we are impaled upon the horn of a dilemma. We find that nature for untold centuries has been wasting this wonderful fuel through innumerable fissures in the rocks. We find the "eternal fires" of Baku fed by it from the remotest times. We find that the Chinese, that people who were formerly always first in every industry and now nearly last used it long ages ago for heating and lighting and use it still. 'Tis said their wells are 3,000 feet deep. In later times came the American money-hunter, that restless variety of the genus homo, who pierced the earth's crust with holes in search of oil, and feeling grieved because enormous quantities of gas only requited their labor, abandoned the places and left holes nearly six inches in diameter, through which gas at unknown pressure has been escaping constantly for years. I think I am within bounds when I state that thousands of these wells are giving off gas at the rate of millions of cubic feet per day. It has been proved by experiment that gas will travel through a 5⅝ inch tube at the rate or velocity of 23,000 feet per minute with a pressure of 20 inches of

water. At that rate I estimate that the flow would be about 5,800,000 cubic feet per day, and would weigh considerably more than 100 tons. About 40,000 tons would be delivered in a year. Now, if the estimate of a thousand producing wells be not too large, we should have a yearly output of over 40,000,000 of tons of gas, or 1,840 billions of cubic feet at atmospheric pressure. Of course, under the pressure at which it is confined, of several hundred pounds per square inch, it would occupy but a small portion of this space. But if it were compressed until it became liquid, it could not have a density so great as water, and would still occupy more than a billion cubic feet of space.

We are, therefore, forced to one or two of these conclusions, viz. : Either gas *is* being produced by some unknown process, or, the supply being wasted, has been overestimated ; or that the supply will soon be exhausted at its present rate of consumption. The two latter conclusions are probably the true facts of the case, but the latter is the more important. Immensely productive wells will cease to be known in a few years, and those districts which are now the most productive will be soonest exhausted. Already we learn of the failure of noted wells. Already noted districts are becoming unproductive. Careful and conservative engineers are advocating laws regulating the sinking of wells and the more economical use of the gas. At Erie, Pa., where gas has been used for a great many years, the supply has fallen off to such an extent that it is now being piped into the city from a distance. I am informed that the Findlay wells are not so productive since so many have been sunk; but the Findlay people deny it. In fact, it seems impossible to obtain correct information on this subject, because nothing is published unless it is of an extraordinary nature, and failures are hidden by parties who either wish to humbug themselves or some one else.

It has been demonstrated that if we in Cleveland wish to enjoy the general use of natural gas we must import it from some one of the more productive fields, which are, unfortunately, a long distance for such an enterprise. Large numbers of wells have been sunk here with varying success, though of a more uniform character than in other places. I have yet to learn of a well which has not given gas when sunk to a depth of 700 feet. Most of them give gas soon after striking the rock, and some of them give it while passing through the gravel which lies upon the rock, but none of them give it in what would be paying quantities if used for fuel.

The following description of a few of these wells is that of all, and may be of interest. The well sunk by Messrs. Lamson and Sessions at their residences on Jennings avenue, to supply their houses, is chosen partly on account of its being a typical well and partly because it came under my notice every day from its beginning until the present time. This well has an 8 inch "drive-pipe," with 5⅝ casing, fitted at bottom with seed bag and cemented between the pipes to prevent blowing out. The drive-pipe was driven 220 feet before rock was struck. Gas began to flow when the rock (or shale) had been pierced a few feet, but in small quantities, and though the drilling was continued to a depth of about 1,200 feet, little if any more gas appeared and no

"blowers" were struck. The well has since been torpedoed, without increasing the flow. The whole product of this well is not sufficient for one house in winter, and will not be more than enough for both in summer. The same parties sank a well at their extensive bolt and nut factory on Scranton avenue about two or three hundred yards from that just described, and on ground about 50 or 60 feet lower. It has the same general dimensions and construction, and was driven 108 feet before striking rock. Gas flowed from the gravel before striking rock and increased with depth, striking occasional "blowers," until at a depth of about 800 feet one of immense size was struck which must have contained gas at a pressure of 100 pounds per square inch. It blew violently from the well for twenty-four hours, after which it gradually subsided to its former condition. No more gas was struck, though the boring was continued to a depth of 950 feet. This well is among the best in this locality, its production being about 18,000 cubic feet per day of gas whose density is .689, free from carbonic acid, and absolutely free from sulphur. A brief notice of the well belonging to Hon. Joseph Poe, near Brooklyne Village, may be of interest. Gas springs have been known for years in that locality, which manifested themselves by bubbling up through the water of Big Creek. Mr. Poe selected a spot for the well near one of these springs and has been rewarded by a copious supply of this luxurious fuel, which besides being sufficient to warm and light his residence in a most comfortable manner, and to illuminate his extensive grounds by lamps which are never extinguished, has an overflow at the safety valve which Mr. Poe estimates would perform four times as much more duty. But the peculiarity for which I selected this well was the great number of "blowers" struck, and the enormous quantity of gas stored, in them at incredible pressure. Mr. Poe tells me that no less than twenty-eight of these unaccountable collections of gas were encountered while drilling to a depth of 750 feet. The twenty-seventh blower was struck in October, 1884. The pressure was so great that it started the heavy boring tools up about 20 feet, where they jammed on the rope. The gas blew so violently that work was suspended until March 1 following. The depth was then 600 feet. On March 4, 1885, at a depth of 750 feet, during the time of the President's inauguration, the boring tools were shot from the well as if by an explosion. The heavy walking beam (a stick of timber 8 × 16) was broken like a reed, and the tools and rope, weighing in all nearly a ton, were projected into the air two hundred feet above the tops of the trees on top of the hill, in all about three hundred feet, with a roar as deafening as a cannon. Mr. Poe, being a good Democrat, feels proud that his well should have celebrated the culmination of his party's triumph in such a handsome manner, though it wasted at least a thousand tons of gas, which would have been sufficient fuel for all of Brooklyne village for a year. The imperviousness of this shale to even such a subtle fluid as gas under such enormous pressure is well illustrated by this example. Not only is there no communication between these blows, but no admonition was given in the way of increased flow, or of any hissing noise which would indicate leakage. Not only this, but the springs which induced Mr. Poe to bore

in this particular spot, flow to-day just the same as they did before. It is evident, then, that a few feet of this substance is sufficient to imprison gas for all time.

Among the most remarkable wells sunk for gas in this neighborhood might be mentioned that of the Cleveland Rolling Mill Company, which, so far as one test can demonstrate anything, proves the futility of probing the earth in this vicinity for large quantities of gas. This company has, with commendable perseverance, bored to a depth of 3,150 feet, at which depth gas was obtained, but not in paying quantities. Between 2,200 and 2,300 feet some gas and some oil were obtained. At 750 feet, in the Huron shale, some gas were obtained, as is usual.

It has been demonstrated, and without demonstration would be admitted as a fact, that as a fuel this gas stands without a rival. Its purity, cleanliness and adaptability have revolutionized some industries, and, *when continuous*, is a great luxury for domestic uses. But it has an almost uncontrollable nature. It seems almost impossible to make pipes so tight or so strong that they will not leak or break, even where the distance from the source is small, but how much greater will be the trouble when the distance is as great as Cleveland is from a productive field? I am of the opinion that, considering the difficulty and expense of bringing it, the uncertainty of its continuance, and the danger attending not only its use but its presence (it kills more than gunpowder), it will be better to do without natural gas.

DISCUSSION OF MR. WOOD'S PAPER ON NATURAL GAS.

Prof. E. W. Morley: I would like to ask Mr. Wood whether he does not think that the evidence is in favor of calling these coals Eocene rather than Cretaceous. In regard to Mr. Wood's supposition that natural gas was formed almost immediately after the deposit of the organic matter, I take a view somewhat different. We know that it is now under a high pressure. It could not have accumulated to anything like the present pressure till it was covered with a stratum. Since such covering would require a long time to accumulate, it would indicate that the process of formation was much slower. Some gas, of course, is produced at once, but the process goes on with greatly decreasing velocity for a very long time, till finally it may almost stop. It seems to me that we are to conceive of that organic matter beginning to decay at once, and for a while gas escaped; but it was a slow process. Then sediments covered this 200, 300, 500 feet thick. After a time the thickness became so great that no gas was permitted to escape except through fissures. The material covering is shale. If that shale be fissured, the fissure does not remain. It is compressed. The shale is plastic, it is like putty under pressure.

Mr. Wood: With regard to the pressure, I conceive that it is due to the superimposed matter, and not to the generation of gas. Prof. Morley thinks that it is due to the generation of gas; my belief is that it is due to the weight of matter upon it. If Prof. Morley conceives that it could have escaped the moment that it was generated, that is another thing. I think that it could not have so escaped. That matter is like a loaf of bread—it works up and becomes light, and continues to contain

gas. Another deposit will put it under some pressure, and as deposits increase, the pressure increases, but the gas does not escape.

Prof. Morley: I do not mean to imply that some gas was not produced soon. I think the main quantity of gas has been produced slowly.

Mr. Wood: Does Prof. Morley think that the hydrocarbons existing in the ground, such as coal and the organic matter which is a component part of this Huron shale, can undergo no further decomposition, or does he hold to the opinion that they are still being formed into gas?

Prof. Morley: We know that the temperature increases as we descend. We know the rate to be one degree Fahrenheit for 48 or 50 feet. If we go down 1,000 feet we have an increase of 20 degrees of temperature. Under a temperature of 75 degrees it is possible for gas to be produced slowly. Suppose that we have a loaf of bread and there be generated in it 10 gallons of gas, it would escape through the pores or blow up the loaf unless we could cover it with some matter that would resist the pressure. Now, if you put it 100 or 500 feet below the ground, you keep the loaf impervious. A quantity of gas would remain in it, but you must have the means of supplying pressure.

Mr. Wood: We agree in the essential details, but not in the matter of time. I conclude that gas would be generated in about 100 years, or geologically speaking, immediately.

Prof. Morley: I would say that 100,000 years might be considered "immediately."

Mr. Rice: What would be the effect of increase of pressure on the formation of gas?

Mr. Wood: Increase of pressure would oppose the formation of gas. If the pressure were sufficient no gas could form. We do not know at what pressure marsh gas becomes liquid, but under sufficient pressure there could be none formed.

Mr. Searles: The paper speaks of the formation of gas in shales as if they were the only sources. It is known that gas is found in other rocks than shale. The Findlay gas is found in Trenton limestone. Gas is also found in sandstone. The depth is somewhat uniform from the surface. The Findlay wells range from 1,100 to 1,200 feet. The great mass of wells run averaging from 500 to 2,000 feet. Admitting it to be a fact that the stratum of gas is such a depth below the surface, it would seem as if there was equilibrium of nature below the surface where materials are at hand for the formation of gas. Gas in one stratum does not communicate with that in another. Where water and oil are found with gas in the same well, the natural order may be reversed. The subject is ably treated in a paper by Mr. Charles Paine, which has been presented to the Club this evening. It was predicted that our oil wells would be exhausted, but we know that our oil industry is to-day of greater importance than when the prediction was made, and in like manner the predictions with regard to the decrease in the supply of gas may not be verified, the gas interest may continue to increase in importance.

Mr. Wood: I think that Mr. Searles will find that I said that the place where you will find most gas is in the porous rock, as it undoubtedly furnishes means for conveying and storing gas. The reason that we have no gas here is because we have no porous rock. The moment we

bore through the different strata of shale, the gas in the immediate vicinity escapes, but the soft rock obstructs that from beyond. On the other hand, the porous rock is sufficiently strong to bear up and form a passage for the gas to get to the well and make an exit.

Mr. Searles : As the Findlay gas is obtained in limestone, it must be porous or have cavities.

Prof. Morley : If it is found in limestone it is because the well strikes a fissure. If it should go down even in porous sand-tone without striking one, it would not get much gas. Suppose your well is fortunate enough to strike a fissure that has a surface of half a square mile, you would then have a large territory to draw from, and a large and continuous supply would result. Even porous rock will not give a great supply unless you strike a fissure, because the resistance soon becomes too great to drain a large territory where so small a surface is exposed.

Mr. Wood : In all the wells in this vicinity we obtain what are called "blowers." I cannot understand what they are. In my first experience with wells I thought they were fissures, but I became satisfied that fissures could not exist there. These blowers are almost all struck at a certain depth. The principal blower in this county was struck at about 750 feet. I could detect no difference between what was brought up from it and the other matter, unless it was just after it had gone through a black shale and had got into blue shale. It is a question whether the alternation of black and blue shale is due to a difference in deposit, or to the shale being decomposed. If it is due to the organic matter being decomposed so as to render the shale a light color, it may be that gas is still being formed by some unknown process of decomposition. I have found a singular piece of shale, blue on one side and brown on the other.

Mr. Holloway: The paper of the evening was entitled "Natural Gas." The discussion so far has treated only of the lighter gas. It is well-known that there is a natural gas, especially about coal mines, called choke damp, a gas which is not inflammable, but which will extinguish flame. I would like to ask what is the difference in these gases? I would like to know what is the difference in the component parts of the gas?

Mr. Wood : It is very natural that people who have not made the subject a special study should wonder. Gases look alike. Marsh gas often accumulates in mines and explodes, then comes choke damp, which is a result of the combustion of the other gas, which is carbonic acid or carbonic oxide. The choke damp naturally formed and this are the same, and the difference in the component parts is in the oxygen and hydrogen.

Prof. Morley : It is always carbonic acid which is produced in the mine. In the nature of the case there would be an excess of air, for you would have an explosive mixture which would not be set on fire if any carbonic oxide were formed; hence, carbonic oxide is impossible.

Mr. Holloway : If the gas is carbonic acid, is it not still natural gas?

Mr. Walker : Mr. Wood has told us of gases that have a strong smell. The gas about Pittsburgh is odorless.

Mr. Wood : I did not say that the gas was strong smelling, but that the

product of distillation of the shale had a strong smell. In this neighborhood the odor of the gas is quite strong. They say that Pittsburgh gas has no odor except when it is fresh from the well, then it has a slight odor. I had a paper which claimed that by standing, the part which has odor and is a liquid hydrocarbon condensed and left the remaining gas without odor. I am of the opinion that the vapor of such light hydrocarbons which may become dissolved in the gas would never be precipitated again except by extreme cold.

Mr. Walker: There has been some attempt to odorize the gas in Pittsburgh. At an engineers' meeting there there was an attempt to odorize it by using bi-sulphide of carbon.

Mr. Gobeille: I think the most important question that has been broached is as to whether the supply is permanent or not. For a time the manufacturers in the gas regions sent out stoves for natural gas only, but I have noticed lately that they are manufacturing them for coal also. There appears to be a good deal of uncertainty with regard to the supply continuing.

Mr. Baker: I understand that in Pittsburgh and other places the supply has been treated as if practically inexhaustible.

Mr. Searles: I have no doubt that it is both exhaustible and inexhaustible, according to the territory. Doubtless if the theory is true that gas is purely of organic remains deposited near the surface, then the supply may stop; but if there is some grand laboratory of nature far down, our globe is large enough to furnish gas as long as the race remains. There may be two sources, one near the surface and the grander reservoir further down. We have evidence of some wells which give no signs of exhaustion. Mr. Neff's wells have been blowing off for fourteen years and are as strong as ever. The well on the Caspian Sea and those in China are in working order to-day. It is evident that some wells are exhausted in a short time and that others continue, and the cause of the difference requires much investigation.

Mr. Latimer: In relation to the gas supply at East Liverpool I have information from observation. The town has been lighted for years from the product of shallow wells about 600 feet deep, and this required the boring of a number of wells. Last year a larger well was formed southward eight or ten miles, which has given a better supply. I must refer to the divining rod to give my theory. By means of it I find that in no case is water, gas or oil continuous anywhere. The gas veins are in columns, and I find that the gases are generated at a great depth. With regard to the well at Newburgh, you know that I predicted the depth at which the gas would be struck, and I was proved correct. I wrote to Prof. I. C. White, of Morgantown, W. Va., and he said that gas should be found at from 1,500 to 2,000 feet below the great salt beds. They found 200 feet of rock salt in that Newburgh well. He said that the horizon of the great gas seams was the same as that at Findlay, and that the horizon of the Findlay wells was several hundred feet yet below where they are at the Cleveland Rolling Mill Company's well.

Mr. Wood: What is the coloring matter of the sand rock last struck at the Newburgh well?

Mr. Latimer: It is black, and when put in to the fire it snaps like saltpetre. They passed through saltpetre.

Mr. Wood: I should like to test it to see whether it is organic matter. Its snapping does not indicate anything. It would seem like magnetic oxide of iron from your description.

Mr. Latimer: I have found indications of gas in every State in the country. I have found it even under the Capitol at Washington. I think that the members are sufficiently acquainted with this subject of testing by the divining rod to know that it is not a superstition, but a scientific question.

Mr. Baker: Mr. Latimer's idea of the formation of natural gas does not appear to agree with Mr. Wood's theory that it was formed principally in the Huron shales.

Mr. Latimer : I did not say that it was not formed there, but that it also came from below.

Mr. Wood : I think that people generally underrate the amount of organic matter that is deposited in the Huron shale. I have estimated that if it were all solid it would be 100 feet thick. It is animal and vegetable together. We know that there were organic remains before the Devonian period, but they were rare. The Devonian or fish period was the greatest previous to the carboniferous period.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

WESTERN SOCIETY OF ENGINEERS.

JULY 5, 1887:—The 238th meeting was held at 8 P. M., President Artingstall in the chair.

The minutes of the preceding meeting were read and approved.

A. N. Talbot, Assistant Professor of Mathematics and Engineering, University of Illinois, Champaign, Ill., was elected a Member.

Applications for membership were received from Wm. A. Lydon, Assistant Engineer Drainage and Water Supply Commission, Chicago.

Mr. B. Williams offered a resolution authorizing the President to appoint delegates to a Convention of Engineering Societies, whenever such a convention should be called, as proposed by the Board of Managers in their report, page 216 JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, 1887. Adopted.

Mr. Gottlieb offered a resolution authorizing the Librarian to secure such assistance as he may deem necessary, and prepare and publish a catalogue of the library of the Society. Adopted.

The Librarian announced the receipt of the last edition of Trautwine's "Engineer's Pocket Book," and "The Economic Theory of the Location of Railways," by A. M. Wellington.

A paper by John Lundie, Notes on Concrete, was read by the author, and discussed by Messrs. Artingstall, Williams, Gottlieb and others.

[*Adjourned.*] L. E. COOLEY, Secretary pro tem.

ENGINEERS' CLUB OF MINNESOTA.

JULY 30, 1887 :—Regular meeting of the Civil Engineers' Club, of Minnesota, was held at City Hall, 7:30 P. M. Present, President Sublette, Messrs. W. W. Redfield, F. C. Deterly, G S. Houston, Wm. De Le Barre, F. W. Cappelen, W. S. Pardee, and C. L Redfield.

Minutes of last meeting were read and approved.

Mr. Cappelen, of the Committee appointed to find out the wishes of the St. Paul Club relative to an excursion, reported that the said Club would like to obtain an individual expression of Members before giving an opinion. The same Committee was continued and instructed to visit the St. Paul Club at its next meeting, settling then the place and date of excursion. On motion, Mr. De Le Barre was added to the Committee. The Committee was further instructed to see to the matter of transportation at that meeting.

Mr. W. W. Redfield reported the receipt of several letters from our members designating place for excursion. On motion the Club decided to select Chicago.

The Secretary reported that a copy of the resolutions relative to the death of Franklin Cook had been sent to the family of the deceased.

The Secretary further stated that an assessment is necessary to meet current expenses. On motion of Mr. Houston an assessment of $5 per member was made.

The Secretary reported that the printing ordered by the Club at a previous

meeting had not been done, it having been found that the Edison repeating method answered a good purpose. On motion the printing order was recalled.

The following were reported as candidates for membership : E. Chrisman, Minneapolis, certified to by F. C. Deterly and Wm. W. Redfield ; Fred. G. Corser, Minneapolis, certified to by G. S. Houston and F. W. Cappelen ; R. Kenrick, Minneapolis, certified to by F. W. Coppelen and G. W. Sublette.

The president read a report of his visit as a delegate to the annual convention of the American Society of Civil Engineers. The report was adopted and ordered printed in the association JOURNAL. WALTER S. PARDEE, Secretary.

[*Adjourned.*]

ENGINEERS' CLUB OF KANSAS CITY.

JULY 5, 1887 :—A regular meeting of the Engineers' Club of Kansas City was held at 8:00 P. M. in the club-room, 19 Deardorff Building, Vice-President J. A. L. Waddell in the chair.

Those present were Clift Wise, Wm. H. Breithaupt, J. A. L. Waddell, Octave Chanute, Clarence A. Burton, A. J. Mason, A. E. Swain, John Donnelly, Kenneth Allen and one visitor.

The minutes of the last meeting were read and approved.

On motion of Mr. Octave Chanute it was voted : That the regular meeting of the Club occurring August 1 be omitted, and that in its stead the Club, on Mr. Chanute's invitation, visit the work in progress at that time of the crossing of the Chicago, Santa Fé & California Ry. over the Missouri River at Sibley.

It was suggested by the Secretary that resolutions of respect be drawn up for Mr. F. M. Harris, late Member of the Club, but no action was taken. The memoir of Mr. Harris, promised by Mr. L. E. Cooley, not having been received, could not be presented, as expected.

The Secretary presented for Mr. H. C. Pearsons his regrets at finding it impossible to prepare the paper on "Standard Time" which he had promised.

Mr. Waddell gave notes on some experiments on the strength of cast iron cable yokes made in St. Louis recently by Prof. J. B. Johnson and himself.

At the request of Mr. Mason, the Secretary read abstracts from the annual address of the retiring President of the Engineers' Club of Philadelphia.

The Secretary presented for Mr. G. W. Pearsons a set of excellent photographs showing the progress of construction on the new Kansas City water-works at Quindaro and Kaw Point, also from the American Soc. C. E.'s reports of the various committees on "Standard Time," with other papers referring to the subject.

Chas. W. Hastings was proposed as Member by Wm. B. Knight and E. B. Kay.

[*Adjourned.*] KENNETH ALLEN, Secretary.

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STREET PAVEMENT—PAST, PRESENT AND FUTURE.

BY JOHN H. SARGENT, MEMBER OF THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read March 22, 1887.]

In treating this important subject I shall give you very little of its literature, but instead give you my own experience and observations.

The oldest pavement I have examined was laid some 2,200 years ago, and, so far as durability is concerned, little improvement has been made since. This was the famous Appian Way, at Rome. It has not been under wear all these years, for it is now buried by the accumulated dust of ages, some feet under ground. In later years, portions of it have been opened up and exposed to view. It was paved with hard trap or porphyritic rock of irregular or accidental dimensions; theyhave a flat surface and looked like and may have been cracked boulders from the bed of the classical Tiber. Some of them were more than a foot in diameter. These were laid first and the interstices were filled in with smaller ones, so that the joints were broken in all directions.

Another interesting pavement I examined was laid about the year one of the Christian era in the streets of Pompeii. These streets, some of them at least, were very narrow, so that vehicles could not pass each other, so they had to go in one direction. Their cross-walks were stepping stones some six inches high, so that the wheels and animals had to pass between them. Before the ashes of Vesuvius came down and filled them up to the second story of the houses, ruts had been worn into them some four inches deep and from four to six inches wide. I was able to measure the gauge of their vehicles, and found it to be our standard gauge, so *that* came down from ante-Christian times, or, perhaps, from the eternal fitness of things.

The macadamized roads across the Alps are great enduring monuments of the skill and enterprise of Napoleon Bonaparte. I say endur-

ing, but a macadamized road without constant care and attention would soon go to ruin. These Alpine roads have this care, and besides, little children six or eight years old are constantly on the roads with their baskets and brooms and sweep up the horse droppings, and all else that will tend to keep up the over-taxed soil. I may as well say just here that a macadamized road is, perhaps, the most suitable of any for a country road heretofore tried, but there is hope in a water-tight floor of indurated clay and asphaltum on a gravel bed. More of this farther on.

I remember a very smooth and perfect pavement in Basle, Switzerland. It was made of cracked hard-heads, or boulders, very hard basalt probably. They were laid with their flat or broken side up, and doubtless upon an indestructible bed and filled in with concrete. It was smooth and clean, but it would hardly stand the heavy teaming of our business streets.

The asphalt pavement of Paris in 1867-8 was a perfect roadway in some respects. It was smooth and noiseless ; horses were not allowed to wear calks and it was very slippery and hard on them. It required constant attention and got it. As soon as a break was made in it, it was fenced off from the rest of the street and was repaired and ironed to a perfect surface and kept fenced off until hardened. Every night these streets were washed off with large hose rigged on rollers.

Now I will come down to business at home. When the lake water was first introduced into Cleveland we had neither pavements, sewers nor street railways. In 1860, Superior street was covered from curb to curb with worn-out plank. This we removed after a pretty hard fight, and replaced with what is now called a Medina wet stone pavement. As the cross-section of this street is now a matter of history only, I will describe it.

The gutters were some twelve feet out from the curbstone sloping up to the curb ; this space was for standing horses and carriages ; between the gutters was 66 feet well crowned, as this form in those days was deemed to give strength to the paving. Twenty years passed and Cleveland had changed from a village in character to a pretentious city. All the level part of the street was occupied by street railways ; the pavement had been frequently disturbed to lay sewers, gas and water-pipes, so that the street had become uncomfortably rough. Then the pavement was renewed and the roadway re-formed to suit the altered circumstances. A percentage of the stone was fit to relay in the least exposed part of the street ; these were used and the balance was laid with new material.

It would, perhaps, be hardly fair, with this experience, to say that with fair treatment the life of a Medina wet stone pavement is twenty years. But with the increased duty upon Superior street I will venture the opinion that the present pavement after twenty years wear will be in worse condition than it was when last renewed. Other of our Medina stone paved streets have been renewed and others need it. Some of the streets have stood, I believe, twenty-five years or more. This is a comparatively durable pavement, but it is rough and noisy and hard on horses and carriages. In the matter of roughness the Medina dressed stone pavement while new has the advantage of being less rough. The wet stone becomes

smoother by age, while the dry becomes rougher, especially where exposed continually to the action of horses' calks, as in the street railway tracks. I do not think the dry stone has any advantage over the wet in point of durability and is much more expensive.

About the time of the introduction of Medina stone into Cleveland, and perhaps before, some streets under the hill, and I believe one half of Superior Hill, were paved with limestone of like dimensions with the Medina. These proved a failure—they would not stand the weather; if, after being laid three or four years, they were taken out they would fall to pieces. One side of Superior street hill was paved with Independence sandstone, from a single layer of flagging near the surface; many of them did good service, but they were irregular in thickness and hardness and in limited quantity. These last and the limestone, I believe, have all disappeared.

About the time of the close of the war the Nicholson pavement fever broke out. I was one of a committee sent by the council to Chicago to investigate. We took up a block in a street that had been paved some four or five years, observed its condition and wear and reported to the council the facts and gave it as our opinion that if the pavement was well put down with good material it would last from ten to fourteen years, according to the duty asked of it. There was a patent upon this particular form of wood pavement. The holders of the patent went for our council hot and hard and the upshot of the matter was that the city bought the right to lay the Nicholson pavement in the streets, paying therefor several thousand dollars. How much of it the owners of the patent got has always been a mooted question. Then began the strife for this particular kind of pavement; its cost was considerable more than Medina stone. It is said that sharp practice was used to secure petitions for the Nicholson pavement, and it was hinted that some influential men got their paving for nothing.

How this may be I cannot say; this I know, that some of the streets were paved with very poor lumber, made from dead timber and timber that was unfit for anything else, and the work was poorly done. The result was that the blocks rotted and disappeared in a very few years while others lasted their alloted time of twelve years. A notable case is Franklin street between Pearl and the Circle. This was paved in the fall of 1869 and the south half of this section has had very little repairs and is a good roadway yet. For some reason the north half has not done as well and should have been renewed two years ago. The service of the south half—seventeen years—is something remarkable; the blocks have not rotted, simply worn out. But the patent was expensive and not good. A far better and cheaper wood pavement is cedar poles cut into eight inch blocks and bedded in good gravel without boards under them. Madison street, Toledo, was paved in this manner with red cedar from Tennessee, and has now stood quite a number of years without repairs and has, as I believe, in no wise failed.

Upon streets with business enough to wear them out before they rot, white cedar would do as well, say for ten or twelve years, while the cost is not one-third of Medina stone pavement, and carriages and horses and their shoes will suffer much less on them than on the stone. These

white cedar blocks are quite popular in Detroit and other Michigan towns. This pavement is so simple in construction that its renewal is made with little interruption to travel. As a question of economy let us compare the Medina dressed block with the white cedar block as a basis. We will assume the stone block to cost $3 per square yard, and to last thirty years, and the cedar block to cost $1 and last ten years, and that the city issue four per cent. bonds to do the work. The sinking fund to redeem the bonds would be ten cents per annum per yard in both cases, with reinvestment something less. Now in the case of the stone the city pays for the stone pavement 12 cents interest plus 10 sinking fund equals 22, and in the case of wood four cents interest and 10 sinking fund equals 14 cents. Hence, so long as the relative cost remains the same it will cost scarcely two-thirds as much to keep a street paved with cedar blocks as with Medina dressed stone.

There is a sanitary consideration to be taken into account as between wood and stone. As soon as the wood begins to decay it fails, and will have to be renewed; until then there is nothing unhealthy about the wood; hence the great importance in putting down sound timber.

All the complicated patent arrangements and preservatives applied to wood in pavements are worthless, and only serve to swell the cost; the simple block set in good sand or ballast is all that is wanted. There may be some better kind of pavement timber than cedar, but it has not yet been found. I do not wish to be understood as advocating wood pavements for Cleveland, for the supply of cedar will give out, and its cost will enhance; but I wish to give all kinds of pavement all the advantages they can justly claim.

Preparations of asphaltum have not so far been a success in Cleveland; their composition is too uncertain and requires too much attention to be trusted in the hands of an ordinary board of improvements. The asphaltum as a top dressing combined with sand, and as an article for filling in the joints of stone and brick, and perhaps wood, is no doubt valuable. For sidewalks an artificial stone or concrete makes a better and more enduring material than our sawed and split sandstone, but it will have a hard fight to compete with it in cost. Broken stone, slag and cinders for city streets are little better than the natural soil.

In conclusion, I wish now to treat of a material for pavement with which we in Cleveland have had little experience. It is so abundant, so accessible, and so cheap withal, that people discard it as but the dust beneath their feet. So it is with many of the most common things in nature; they often turn out to be our greatest blessings. Petroleum and natural gas took many years to demonstrate their capabilities. Clay, the ore of aluminum, when properly manufactured and burned, becomes what may be called an igneous rock, unaffected by the weather, water or fire itself. It will stand more pressure in the testing machine than the best of granite. It is homogeneous and slightly elastic; it will neither act upon the horses' shoes nor be acted upon by them. I speak now of brick made of fire-clay. They should be burned hard enough to partially vitrify the molding sand on their surface. In this condition you cannot sharpen your axe upon them, nor wear away their surface by attrition. The tenacity and wearing quality of an ordinary brick is re-

markable. The mason, when he has to shape a brick, will not attack a hard burned one; if he does, watch him, and see how little effect he has upon it with his sharp steel trowel. Look at our tall brick buildings, and see what pressure ordinary brick have to sustain. The walls of my own homestead have stood the buffetings of sixty alternating seasons of frost and heat and storm unimpaired. The bricks of the old Roman ruins, shattered by earthquakes, fire and war, stand out sharp and jagged; these bricks are but one and a half inches thick, but they, the individual bricks, are now as sound and solid as they were two thousand years ago.

It is thought that the fire clays of our coal measures will produce a better brick for pavements than our common red clays.

I am inclined to think this is so, but the common brick have been used in Charlestown, West Virginia, and Bloomington and other towns in Illinois for a dozen years. Some taken up after ten years' wear had been worn down less than a quarter of an inch. Experience only can determine the best clay and best treatment. Last fall a small section of fire-brick was put down in the street railway track at the intersection of Detroit and Pearl streets, and another at the intersection of Ontario and Michigan. I would invite the members of the Club to examine them. I can see no perceptible wear or deterioration. Aside from the question of durability and economy they make a very smooth, quiet and dustless street. There are certain patent schemes for brick pavement, but they are all "no good," and come under the same category with patents on wood pavements. A perfectly formed and consolidated roadbed made by rolling or pounding and covered by a single course of bricks laid edgewise with the joints filled with hot asphaltum and sharp sand makes a perfect, continuous floor, on a foundation that cannot escape.

The only pavement that can now come into competition with this in Cleveland is the Medina sandstone pavement. We will now examine this material. The Medina sandstone is a very compact and hard sedimentary rock. All sedimentary rocks are, however, laminated, and have a cleavage parallel to the beds, and they are laid in the pavement in a way favorable for the horse calks to act upon them. As a result, observe the stone in the railway tracks in Superior street and on the Viaduct, and you will see the dressed stones converted into boulders as rough as any well laid boulder pavement. There is another cause for the wearing away of a sandstone, however hard it may be; it is composed of silicious particles that will "bite" iron and steel. The same force that acts upon the shoe reacts upon the stone. The grindstone cuts away the steel tool but the tools ultimately wear out the grindstone. Clay or brick has no grit that will bite steel, and on that account will not be reacted upon by the steel; so they cannot destroy each other. From my observations I believe a brick pavement can be made to outlast in good condition a Medina stone pavement, and will cost much less; how much less we shall soon see. If it should be found on investigation that the fire-clays are the most suitable for pavement they exist in great abundance within easy access to Cleveland by canal and rail.

The chemical constituents of the clay should be taken into account. It is clay that gives the hydraulic quality to the water limes. The physical

qualities of fire-clay may be divided into the hard and the soft plastic, but not differing greatly in their chemical constituents. Singularly enough, the plastic has less combined water and alumina and more silica than the hard. On this account I should expect the hard to make the better brick for paving. Lime, uncombined at least, would probably be deleterious. Here is a specimen of the hard variety from New Cumberland, West Virginia, on the Ohio River. There it is burned with natural gas in down draft kilns or ovens. They may be burned in the same kind of oven with slack coal to any degree of hardness required, as they are in Tuscarawas County. One happy circumstance is that the bricks too soft for pavements are better for furnace linings than the harder ones, and worth quite as much.

Individual residents of Franklin avenue, being in West Virginia, observed some of these brick pavements, some that had been down three years, some twelve, and were struck with their smoothness and good condition A public meeting was called and a committee was appointed to gather information. They went to Wheeling and examined the pavement, and to New Cumberland to examine the material and its manufacture. The committee was very favorably impressed, and reported advising the use of fire-brick for Franklin avenue—here are several letters received by the Committee which the Club would perhaps be glad to hear read; if so, I will ask Mr. Holloway to read them.

The Board of Improvements has advertised for proposals for both brick and Medina dressed stone pavement. When these bids are opened we shall be able to see the relative cost. If the specification prepared for the brick pavement by the board have no unnecessarily expensive requirements, I shall expect the brick pavement to cost little if any more than one-half the stone. At the same cost, and I have a long front to pave, I should much prefer the brick. The cost of a foundation for the one is practically the same as for the other. The brick will have a more perfect bearing than the stone, for the bricks have a full bearing bed all alike, and are of the same depth, while the stone are of unequal depths, and the lower end more or less wedge shaped. The bricks will fit far closer together, and hence will require much less asphaltum filling, and having a smoother surface will shed off the water more perfectly.

This paper has been prepared very hurriedly, as I supposed until this morning that I had two weeks more in which to finish it.*

DISCUSSION.

At the close of his paper, Mr. Sargent announced that he had with him a number of letters on the subject of street pavements, and if it was the wish of the members present they would be read by Mr. J. F. Holloway.

Mr. Holloway, at the request of the Members, then read the letters as follows:

Mr. Holloway first stated that these letters were replies to inquiries

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* Since this paper was read, the dressed Medina stone pavement in the street railroad tracks on the Superior street viaduct, laid in 1879, have been taken up and relaid. Nearly all of them had to be redressed and a notable percentage of them replaced by new stone, while the brick pavement laid in the same tracks at the Detroit street crossing last fall show little or no signs of deterioration.—J. H. S.

made with the view of going to the root of the matter, and were written by persons who had no interest in pressing the claims of any pavement.

A. H. Bell, City Engineer of Bloomington, Ill., stated that the citizens were highly pleased with the brick pavements. The bricks are ordinary clay brick burned very hard—almost vitrified. Where there is no grading or foundation to prepare, the pavement costs $1.15 per square yard laid down.

P. Whitmer, of the People's Bank, Bloomington, stated that since Bloomington had tried brick pavements, Galesburg, Jacksonville, Champaign and other cities had adopted brick, and all were pleased with it. In Bloomington, an inch of sand was first put down, then a course of brick, laid flat, on which was placed a thin layer of sand, then a course on edge as close as convenient, say a quarter of an inch apart. On top of that enough sand to fill the interstices, and it is done.

Mr. Holloway stated that the city engineer of Bloomington had read a paper before the club in Chicago in which he spoke highly of the brick pavement in use in Bloomington.

Mr. Whitelaw: I suppose they lay double courses there on account of the clay soil.

Mr. Holloway: I think they do it with the idea of getting more surface.

The "Riverside Steel Co.," of Wheeling, W. Va., stated that the citizens were so much pleased with the brick pavements that they were being used to the exclusion of every other kind. Those laid three years ago do not show any appreciable wear, and they do not become smooth and slippery in winter. They are almost noiseless, and are easily swept and kept clean. The drainage is quick and complete. The pavements can be built at a cost of $1.60 per square yard, which includes all material and labor and preparing a bed to receive the substratum of gravel or sand. The blocks are 9″ × 3″ × 5″, and weigh 9 lbs. 10 ozs. each.

J. M. Doddridge & Co., of Wheeling, W. Va., stated that the Board of Public Works had put down over three miles of fire-brick pavement, and would continue to put it down on all streets needing improvement.

Delegations from Columbus, Zanesville, Pittsburgh had been at various times at Wheeling with regard to this subject, and fire-brick is being tried in those cities.

A. Laing, of Wheeling wrote that an experimental street paved some years ago with brick looks as good as new.

J. P. Hale, of Charleston, W. Va., stated that the clay used for paving brick was simply a good quality of common building brick clay, tough, stiff and tenacious. Such clay could be found in the vicinity of almost any city in the United States. The writer believed that brick would eventually supersede every other material for street paving. In his opinion it is not only the cheapest, but the best material that can be used.

Prof. I. O. Baker, of the School of Civil Engineering, Champaign, Ill., stated that the cost of brick pavement varied there from $1.60 to $1.87 per square yard according to the freight on brick or sand. It had been tried 3 years and no sign of wear could be discovered. For method of laying Prof. Baker referred Mr. Holloway to an editorial from his pen in *Engineering News*, Vol. XIV., page 330, Nov. 21, 1885.

W. McD. Hiller, of Steubenville, O., said that a test square of vitrified fire-brick set on edge was put down three years ago, and had not cost a cent for repairs since. Parts of several streets are now being paved. Some blocks cost as little as 85 cents per square yard, including everything. Others cost more because the excavated materials have to be hauled further, and because there is not a natural foundation of gravel; but all cost under $1. The hard-burned red brick stands five tons pressure; the new Cumberland fire-brick, eighty tons pressure. It is smooth but never slippery; horses never slip on it in winter.

The prospectus of the "Hale Pavement Company," of Staunton, Va., containing a large number of testimonials from various cities, was referred to by Mr. Holloway. This company claim that their pavement is durable and serviceable, economical, clean, healthful and comfortable and noiseless. The material for the pavement is, first, sand, then boards dipped in hot coal tar, then hard-burned brick.

Mr. Holloway: Last fall, in Allegheny, I saw a street paved with fire-brick. The street has residences on one side, and on the opposite side there are terraces sloping down to the depot. The first thing that struck me was that they were laying courses of brick flat ways. I asked a gentleman why they did not set them on edge. He replied that they were trying an experiment. I said that I supposed that they would have put lower courses of good red brick. He said that there was not much difference in the cost. A gentleman who was passing stopped and said that the way in which this was being laid down would not answer. The agreement was that they should have just such a street as the block above. From what was said afterward, I gathered that the people were very much pleased with the paving of the block mentioned, which had been laid over a year. I walked then to the block above. It was very clean. I did not see a broken brick or a soft brick in the whole street. While I was there a great many teams passed. It was a little down grade, but they never halted, showing that the horses had confidence in it. I listened for the sound of the wheels. I could hear the click of the horses' feet on the pavement, but there was no rumble of wheels. It was almost noiseless.

Mr. H. M. Claflen: As to Medina stone, I could read a number of letters giving favorable criticisms, but I do not wish to put myself in the light of a patent medicine vender. The people in Bloomington have no stone. The brick pavement is a great improvement upon the mud. So with the other little towns. What do the people in Harrisburg know about pavements? Of all the slow-growing places in the world, Harrisburg will take the palm. When you go to cities that are cities, do you find them adopting fire-brick, or any other brick? I saw in San Francisco one street paved with brick. It is the only street, so far as I can learn, ever paved there with brick. Brick was put down in Chicago and has been taken up. In St. Louis they went to great expense and tested all sorts of pavement. Did they adopt fire-brick? No, they adopted granite. The City of Toledo was about to pave one of its streets. A fire-brick man tried to induce the people to adopt his pavement. I went up there, and last night the contract was awarded me. The Topeka people have tested all kinds, and have declared against fire-brick, and have adopted stone and asphalt. I

am going to lay it down as my creed that an artificial pavement, if any other can be had, is a very foolish device. When the material is subject to the action of the weather, horses' feet and so forth, the artificial pavement may not be enduring. The only material practicable for pavement is stone. When you lay it well you get the best results. Mr. Sargent compared wood with Medina stone. He placed the lasting qualities of Medina stone at thirty years and those of wood at ten years. If you look at any street paved with wood that has been down for ten years, you will see that it has been down at least three years too long. I can show Mr. Sargent a street where the stone was laid down fifty years ago. I want to ask, as an engineering problem, how long a street laid with block pavement will last? River street was laid thirty years ago. A year ago last Summer we took up a part and relaid it. If any one will examine it he will see that it is one of the prettiest pieces of pavement to be found, though it was laid in an unmechanical manner. You can see Medina stone in your own city. In Buffalo you can see 100 miles of streets paved with it. It is as lasting as granite; it is not as noisy nor as slippery. You can saw and polish granite, but you cannot saw nor polish Medina stone. I examined some granite laid on Fifth avenue. It is laid much like Euclid avenue block stone pavement, but it does not begin to compare with the block stone pavement laid in Cleveland.

Mr. Whitelaw: In Omaha they are using a pink granite.

Mr. Sargent: I do not think there is any stone equal to the Medina stone for pavement.

Mr. Whitelaw: Mr. Gordon Lloyd laid down a good deal of brick in livery and other stables. His process was to heat the brick and dip it in coal tar. He said this made it impervious to water and to frost.

Mr. Sargent: A car-load of bricks was put down in Pearl street, and one at the corner of Prospect street. There was a top dressing of hot asphaltum. I cannot see that there is any wear in it.

Mr. Claflen: My conundrum is this—How are you going to say whether fire-brick is soft or hard?

Mr. Sargent: You cannot always tell about Medina stone. Bricks do not require to be burnt so long for livery stables as they do for paving. I have had nothing to do with fire-bricks except with these two carloads. Perhaps when fifty years go by we may know as much about brick pavements as we do now about Medina stone. A short time ago the use of gas and petroleum was thought detrimental, now we could hardly do without them.

Mr. Herman: In my native city, Prague, there was an experiment made in 1857. A block in a street was paved with brick in herring bone style. The city is paved even to the narrowest alleys. After considerable agitation a permit was obtained to lay a block with this brick pavement. It was taken up in a year as unfit for the purpose. Brick is used extensively in this city for paving floors. The bricks have to be frequently replaced. I notice here some sidewalks paved with brick, and I often stub my toe on them. In Akron I found a number of pavements with tiles vitrified, and tiles are used in this city in driveways on Euclid avenue. I see that many of them are destroyed.

Mr. Latimer: I agree with Mr. Claflen upon the question of stone pave-

ments, but we must always be ready to consider a new idea. The testimonials are apparently from places where they cannot procure good stone. Their time of trial is but short compared to that which we have had here. Everybody remembers the testing of wooden pavements. Those who saw far enough saw that the change to wooden pavements was a foolish one. It was a waste of money. To commence a new system of paving, following the lead of western towns, or towns that have no paving stone, would be a foolish thing for Cleveland. In my opinion a good stone is unquestionably the best material for paving. If the city of Cleveland should try brick pavements it should be done with the greatest caution.

Mr. Paul : One difficulty I anticipate in using bricks for the purpose of paving is, the variety in their quality. Undoubtedly, some bricks are very durable, as we find them still in good condition in ancient cities, but so far our experience in this city would show that they are not durable. The pavements of nearly all of the school buildings were laid in brick. A number of them had to be relaid. They seemed to be going to pieces from being trodden by the school children. This was very noticeable in Rockwell school building. I do not mean to say that bricks may not make a very good pavement. One objection to our stone pavement is that many of the stones are wedges, others are broad; of course this makes an uneven surface. The bricks are uniform. Where there may be considerable traffic in these towns I would like to inquire if any of the bricks have broken in the middle by the cross strain, or does the wedging hold them.

Mr. Holloway : The question is interesting to every one. Sewerage and pavements are among the most important unsolved problems. I am not one of those people who are in the habit of running after a new thing. The proper material for paving the streets of a city has been spoken of as if the streets of a city were different from streets elsewhere. There are in all cities streets which have to bear nothing heavier than the grocer's wagon and the doctor's gig. Because the main streets of a city require enduring pavement, that therefore the question of endurance is to be the only one taken into consideration is preposterous. While I am prepared to say that the recently laid pavements of Medina stone are very fine indeed, I am not prepared to say that it is the only material for pavement. The question of living on a quiet, smooth, clean street is to be considered. One idea in the introduction of the wooden pavement was to have some rest from the noise of the rough stone streets. A stone street is an undesirable one for private residences. People who have lived on Pearl street have been obliged to leave it on account of the noise. There is hardly a public building in this city where you can listen to an address with any degree of comfort on account of the noise of the stone pavement. For my part, while I have great respect for posterity, I think it can be proved that streets lasting 15 years may be renewed with greater economy than those lasting 50 years. I am not prepared to say that the most enduring material is in every respect the best for the purpose. It has been demonstrated that brick is the best for all building purposes. Costly buildings of stone in Chicago were blistered and burned almost beyond recognition.

Mr. H. C. Thompson : When Dr. Jayne's granite building was burned in Philadelphia on a frosty night the stones flew to pieces.

Mr. Sargent: Granite will not stand fire.

Mr. Holloway: I have not said anything in disparagement of the excellent stone streets that we have had for years, but I believe that there are miles of streets that have but little traffic on them, and if they can be made comfortable, cleanly and wholesome by the use of fire-brick, or any other brick, it will be a benefaction to the people of Cleveland. There are miles of streets that should be paved with stone. I know that the main street of Wheeling is a street of heavy traffic. It was filled with four and two horse teams hauling the heaviest kind of material. I have no interest whatever in this matter beyond that of living in a quiet residence street.

Mr. Claflen: Mr. Holloway is mistaken if he thinks for a moment that my heart is broken because he wants fire-brick on Franklin avenue. There is one thing that I would like to say: in all these comparisons of costs there has been unfairness of representation. They propose to put down fire-brick about four inches in depth. In Medina stone they use seven or eight inches. It has been represented to the people that they could get a pavement for $1.20 a yard. In Columbus the price was $1.80 per square yard. In Toledo is was $2.25. Medina stone dry pavement is about $1.80 a yard.

Mr. Holloway : I do not know what the cost of this material is. In regard to the depth of the material, I think Mr. Claflen is very modest in his statements. I have seen stone pavements here over a foot in depth. In times past very little care was taken as to the shape of the stone. One of the advantages in brick is that it has a perfect bond. The ends are supported by each other and the sides are supported by the adjoining brick. Where all is held by the abutting brick, there must be additional strength to the whole. The effect of any pavement that has joints in it is that the calks of the horses' feet will break off chips. When the pavement was laid upon the viaduct it was smooth, now it is very rough. It has been worn where the horses' feet strike till the stones look like old cobble stones. The other part of the road is smooth, but smooth at the cost of the material below. I think that any material which presents few or no joints, few or no parts for the calks of the horses to break off the edges is advantageous.

Mr. Claflen : When the pavement was laid on the viaduct it was the first work of the kind laid here. The stone was not even gotten out by expert men. The pavement going up the hill is to-day one of the finest pieces of work that I have seen. It is true that the stones in the tracks are worn off a little, but I should like to have any one discover a material to put in a street railroad track that will last when it has been down ten years. That on the sides is not so much worn. The shoes of the street car horses are kept much sharper than those of ordinary horses. If you account for the smoothness of the sides from the fact that the stone is worn down I think you make a mistake. I would like to show the pavement going up the hill to any man in America to-day as a piece of first-class work.

Mr. Sargent : I want to say a word about the much-abused wood. They say in Detroit that wood will last about ten years. In 1869 a street on one side of my residence was paved with the Nicholson pavement. It is quite

a good piece of road yet. I had no idea that the material could last so long. On the other side is Medina stone pavement, and on Pearl street it is very hard to hear your neighbors. Now Pearl street has a great deal of business, and it is possible that such streets require a stone pavement, but I would rather have such a street as Franklin avenue laid with cedar, on account of its noiselessness and cleanliness. In Wheeling I did not see any streets that were broken. I have always been a great advocate of the Medina stone pavement. I think it is superior to any stone pavement, unless it be the basalt pavement.

Mr. Claflen : It has been observed that where the trees shade a street and keep it moist, it is much less decayed than the other side.

Mr. Sargent : A cedar pavement is cheap, easily renewed, and a pleasant pavement.

Mr. Whitelaw : I made an examination of the wooden pavements in Chicago and brought some blocks home with me. They vary in depth from two to four inches. The wooden pavement is noiseless and pleasant.

HISTORY OF THE LAKE SHORE & MICHIGAN SOUTHERN RAILWAY.

By C. P. Leland, Member of the Civil Engineers' Club of Cleveland.

[Read May 10, 1887.]

It is evident that the Lake Shore & Michigan Southern Railway, lying in six great States, with 1,340 miles of road, 266 miles of second track, 555 miles of side tracks, making in all 2,161 miles of track, with 526 locomotives and 16,992 cars adapted to every kind of business, is an important factor in the welfare of many millions of people, not only in this country, but in the old world as well. A hasty glance at its business for 1886 gives abundant proof of this.

It transported in 1886 3,715,508 passengers an average distance of 51½ miles, rapidly and safely, for the moderate average compensation of $1.08 each. This is equal to 10,180 for each of the 365 days. In the same year it transported 8,305,597 tons of freight (22,755 per day) an average distance of 192 miles.

And how cheaply this was done. When next you hire an express wagon to haul a load of stuff a mile, paying therefor a dollar, which is cheap enough, just remember this fact, that the average pay received by this road in 1886 for transporting one hundred tons one mile (about six large car-loads) was 64 cents. Small as this was, it was 9 cents more than the average of 1885.

What was the result of this slight improvement which hurt nobody? It was the signal of the dawn of better times, after the long night of depression, and, instantly, fires were started in idle rolling mills, locomotive and car works, and every industry in this great land, even gas and oil and real estate booms, felt the improvement in the trade barometer. This little improvement gave the long suffering four thousand stockholders of the Lake Shore & Michigan Southern a little dividend of two per cent., or a million dollars, to be poured into the arteries of trade.

As this road operates only a little more than one per cent. of the rail-

road mileage of the United States. I leave it to your imagination to estimate the aggregate benefit of a little more pay for this mighty torrent of freight.

I started out by saying that this road is a benefit to millions of the overcrowded population in foreign lands; one single fact will establish it. Meat is carried from the great packing houses in Chicago one thousand miles by rail to the seaboard, thence three thousand miles by water to Liverpool, for 40 cents a hundred pounds, or less than half a cent per pound. The L. S. & M. S. Railway performs more than half the thousand miles of rail transportation.

There are on the pay rolls of the L. S. & M. S. Railway the names of 10,400 men, among whom were distributed $510,000 in March. Then there is another large army of men working for the company indirectly making steel rails, building locomotives and cars, mining the 1,250 tons of coal consumed every day, and manufacturing the many minor supplies used. It is safe to say that one-tenth of the large population of the United States gain a livelihood by working for railroads, either directly or indirectly.

Pardon me for referring again to the low prices of freight the past few years and comparing it with former years, before the great Bessemer gave the world steel rails. Take for the unit the one I have used—100 tons one mile—the average paid by the public was:

In 1854	$3.51	
In 1860	2.16	
In 1865	2.90	
STEEL RAILS.		
In 1870	1.50	
In 1875	1.18	
In 1880	.75	
In 1885	.55	No dividend.
In 1886	.64	

The rate for 1886 was but 30 per cent. of the rate of 1860. These figures demonstrate the interesting fact that every dollar of the benefit derived from Bessemer steel rails has been enjoyed by the consumer, not by the railroads.

If it does not, here is another fact that will. In the last seventeen years, since the introduction of Bessemer steel rails, the aggregate of dividends paid to the stockholders of the L. S. & M. S. Railway was 88 per cent.—a trifle less than 5¼ per cent. per annum. For the seventeen years prior to that, when iron rails were used, the uniform rate of dividend was 10 per cent. per annum.

Of course there are other causes for this; but the tremendous reduction in rates of freight is the principal one, and this was made possible by Bessemer steel rails.

This road earned in 1886, $15,859,455, and it has averaged for 17 years $16,006,161 per annum.

Now it is my opinion, after considerable thought and research, that the aggregate earnings of all the craft trading upon this great chain of lakes, from the St. Lawrence to the heads of Lake Superior and Lake Michigan, never in the most prosperous year enjoyed earned ten million

dollars, which is considerably less than this road earned from freight alone in 1886, even at the low rates I have given.

The history of the growth and development of this great railroad system from beginnings so insignificant as to seem ludicrous now, has been of intense interest to me, as I trust it will be to you. I have drawn it largely from the official records, hence it is at least accurate.

In 1868 what is now the Lake Shore & Michigan Southern Railway Company was in four companies, to wit :

The Buffalo & Erie.

The Cleveland, Painesville & Ashtabula.

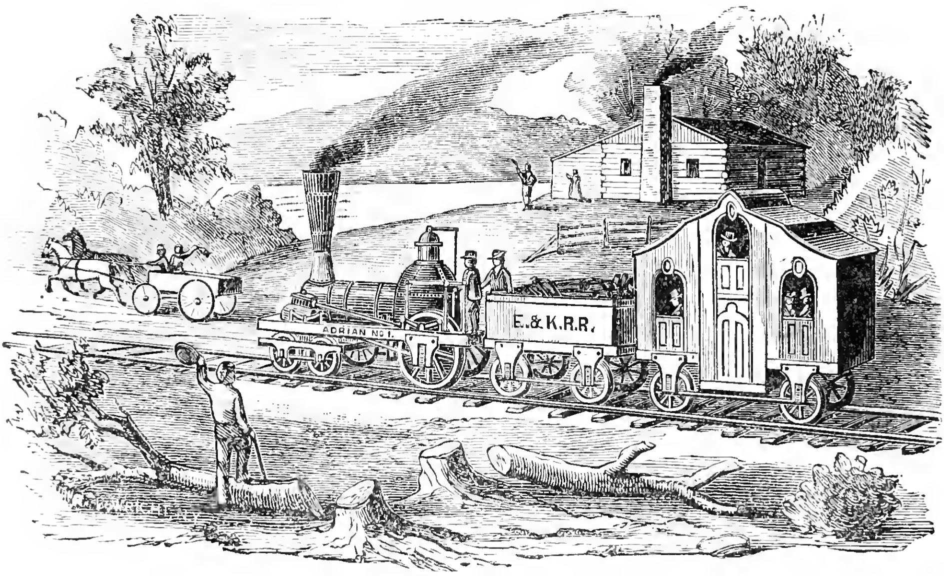
The Cleveland & Toledo.

The Michigan Southern & Northern Indiana.

By a singular coincidence these four companies were each a consolidation of two companies, making eight original companies.

The time allotted me will permit of only a hasty glance at the history of each. I shall take them up chronologically.

ERIE & KALAMAZOO RAILROAD.



First Locomotive and " Pleasure Car " on the Erie & Kalamazoo R R (between Toledo and Adrian, 33 miles). Time, from 4 to 10 hours ! 1837.

In 1833, the then territory of Michigan, with a population of only about 35.000 (nearly 2,000,000 now) incorporated a company to build a railroad from Lake Erie at Port Lawrence (now Toledo) to the head waters of the Kalamazoo River, giving the company the title of Erie & Kalamazoo.

At that time the entire road was claimed to be in the territory of Michigan, but on the final adjustment of boundaries, after the celebrated and somewhat ludicrous Toledo war, about one-third of the road—eleven miles—was in Ohio.

The track consisted of a thin iron ribbon spiked on oak stringers, and would be rejected as a street railroad now. It was opened in 1837, the motive power being horses or mules for a considerable period.

In that year, however, the first locomotive in the tier of great States bordering on the great lakes, and the third locomotive west of the Alleghanies, arrived at Toledo on a lake vessel for this road. It was named the "Adrian," built by the Baldwin Locomotive Works, and was their No. 80. Up to May 9, 1887, that great industrial establishment had turned out 8,537 locomotives.

Here is a copy of a local item from the *Toledo Blade*, 1837, respecting this little 10-ton locomotive, also the regular advertisement of the road, in which, it is noticeable, no time is given for the departure of the train. It left when it got ready!

"It affords us pleasure to announce the arrival of the long expected locomotive for the Erie & Kalamazoo R. R. The business of our place has been embarrassed for want of it; goods have accumulated at our wharves faster than we could transport them into the interior on cars drawn by horses, and, as a natural consequence, several of our warehouses are now crowded to their utmost capacity. It is expected that the engine will be in operation in a few days, and then, we trust, goods and merchandise will be forwarded as fast as they arrive. A little allowance, however, must be made for the time necessary to disencumber our warehouses of the large stock already on hand.

ADVERTISEMENT.

TO EMIGRANTS AND TRAVELERS.

The Erie and Kalamazoo Railroad is now in full operation between

TOLEDO AND ADRIAN.

During the ensuing season trains of cars will run daily to Adrian, there connecting with a line of Stages for the West, Michigan City, Chicago and Wisconsin Territory.

Emigrants and others destined for Indiana, Illinois and the Western part of Michigan

☞ *Will Save Two Days* ☜

and the corresponding expense, by taking this route in preference to the more lengthened, tedious and expensive route heretofore traveled.

All baggage at the risk of the owners.

EDWARD BISSELL,
W. P. DANIELS,
GEORGE CRANE, } Commissioners E. & K. R. R. Co.

A. HUGHES, Superintendent Western Stage Company.

For ten years this road had a stormy and troublous existence, its affairs being managed sometimes by a commissioner acting for the board of directors, sometimes by trustees appointed by order of Court, and part of the time by a Receiver at the Toledo end and a Commissioner at the Adrian end, recalling the familiar anecdote of the retort of the mate of a vessel to the captain, "My end of this craft has come to anchor."

In 1848 the road was sold out under accumulated judgments. Hon. Washington Hunt, of Lockport, N. Y., and George Bliss, of Massachusetts, were the purchasers.

They leased the road August 1, 1849, in perpetuity, to its rival, the Michigan Southern, then in operation from Monroe to Hillsdale, and, although it forms a part of the main line of the Lake Shore & Michigan Southern from Toledo westward, the Erie & Kalamazoo Company still exists, drawing and dividing its rental of $30,000 per year. This first consolidation settled the struggle for supremacy between Monroe and Toledo in favor of the latter.

The following account of a day's pleasure in (and out of) the "Pleasure-car" in 1841 is both interesting and amusing:

To the Editor of the Toledo Blade:

During most of the year 1841, I was employed as repairing agent of the Erie & Kalamazoo Railroad, then in operation between Toledo and Adrian. According to schedule time, a passenger train with one coach would leave Toledo in the morning, make the run to Adrian, and return to Toledo in the afternoon, arriving about 6 P. M. The passenger car then used was about the size now in use upon our city street railroads, and was divided into three compartments, each having a front and rear seat, facing each other and running from side to side of the car, with a side entrance to each compartment. The track was ironed with the flat bar "strap rail," as it was called. As my home was in Toledo, I found it necessary to go on each Monday morning over the road, spending the week in making such repairs as were necessary, and returning home on Saturday evening.

In December, 1841, one Saturday the train left Toledo on time for Adrian. I was then at Palmyra, intending to take the train for Adrian and return to Toledo that evening. Owing to a severe storm of rain, freezing as it fell, the track became covered with ice. The train reached Palmyra about 4 P. M. I entered the middle compartment of the car, as the train started for Adrian, and met in the car J. Baron Davis and wife, of Toledo, sitting in the forward seat. Being acquainted with them I thought I would take a seat with them, but seeing the cushion upon the seat out of place, I took the rear seat, facing the one I had rejected. We had not gone more than half a mile from Palmyra, when a "snake-head," as they were called (the end of a loosened bar), came crashing through the floor of the car, passing diagonally through the seat I had left vacant, the end of the bar striking me in my neck under the chin, and pushing me backward with such force as to break through the panel work partition which divides the compartments of the car. Just at this moment the other end of the bar was torn from the track and carried along with the car. Recovering my consciousness a little, I found myself with head and shoulders protruding through the broken partition, while I held the assaulting "snake-head" firmly grasped in both my hands. Being a stormy day, I had an extra amount of clothing about my neck, which the bar did not penetrate, so that my injuries were not serious. The train was stopped. Frederick Bissell, the conductor, was much frightened. Before leaving the spot, the guilty "snake-head" was once more spiked down, and we moved on, reaching Adrian at 6 P. M., having made the run of 33 miles in 10 hours.

This train left Adrian for Toledo at 7 P. M., and worked its way along over the ice-covered track until we got out of wood and water, when we picked up sticks in the woods and replenished the fire, and with pails dipped up water from the ditches and fed the boiler, and made another run toward Toledo. Passing Sylvania we got the train to a point four miles from Toledo, when, being again out of steam, wood and water, we came to the conclusion that it would be easier to foot it the rest of the way, than to try to get the train along any further. So we left the locomotive and cars standing upon the track, and walked into the city, reaching here about 2:30 A. M. I was rather lame and sore from contact with the "snake-head," but gratified that we were enjoying the "modern improvement"—railway travel.

M. BRIGHAM.

TOLEDO, January 13, 1882.

MICHIGAN SOUTHERN.

In 1837 the Legislature of the State of Michigan projected and made provision for three railroads and one canal or railroad running across the four most southerly tiers of counties, which, at that time, embraced nearly all the settled part of the State.

For the survey, location, construction and management of these roads, together with the improvements of certain rivers, and other minor improvements, they organized a Board of Internal Improvements and provided for a loan of $5,000,000. (Nothing mean about Michigan !)

Prior to this time a number of railroad companies had been authorized to be incorporated by the territorial legislature, and three of them had made some progress in the construction of their respective roads. The oldest of them, the Detroit & St. Joseph, was nearly finished to Ypsilanti, but had not commenced running the road. The franchises, rights and property of this company were purchased by the State, and their line became a part of the Central Railroad intended to run across the State through the second tier of counties. The company had expended about $117,000, which amount the State paid, taking the road.

The Detroit & Pontiac Railroad was about completed, and although the State aided that company by a loan of $100,000, the company continued in possession of the road, which is now a part of the Detroit, Grand Haven & Milwaukee Railroad.

The Southern road was one of the projects of the State—authorized in the act of March 20, 1837. It was intended to run across the State, east and west, through the most southerly tier of counties, from the navigable waters of the River Raisin, near Monroe to New Buffalo, on Lake Michigan. (Chicago then was a mere Indian trading post, with Fort Dearborn in a quagmire.)

It goes without saying that in the terrible crash which followed the wild real estate boom of 1836–37, when everybody "busted," Michigan did not get left. She "busted, too," and had a couple of unfinished strap railroads for sale. The Southern road, Monroe to Hillsdale, 68 miles, with the Tecumseh Branch, 10 miles, a total of 78 miles, was sold to the Michigan Southern Railroad Company, with Edwin C. Litchfield as its head, for half a million dollars. Pretty cheap, especially as the purchasers got long time, and met the installments with depreciated State scrip bought up at 50 and 60 cents on the dollar. But Michigan was no hog. She knew when she had enough, and about that time she was very earnestly hunting for somebody to help her let go. In this particular she was not unlike a good many Congressmen of to-day who voted for the Inter-state Commerce bill. When their constituents get at them next time it will not avail them to plead they "didn't know it was loaded." They ought to know that the great laws of supply and demand, and excessively severe competition can be trusted to protect the people in this, as well as all other business.

The transfer of the Southern road was made December 23, 1846. J. H. Cleveland, who is still living, was the superintendent of the road for the entire period of its operation by the State, 1840 to 1846. At the first meeting of the board of directors of the new company, the following quaint resolutions were adopted :

"*Resolved*, That no credit be given for freight or passage." (A steamboat phrase.)

"*Resolved*, That there be appointed two conductors, or captains of trains, who shall perform the duties of collector of freight and passage money, at $40 per month."

After a long and careful consideration of this important business, one, Timothy Baker, was elected. The other was left to be nominated by the Hillsdale stockholders. Little was done during the first four years after the purchase, beyond getting a "good ready," raising money, developing the great steamboat business on Lake Erie, etc., but in 1850, 1851 and 1852 a grand construction race for Chicago was going on between the Michigan Southern and Michigan Central. It was a neck and neck race, both roads reaching Chicago in May, 1852. Our honored member, Mr. J. H. Sargent, bore a prominent part in this great construction, as well as in that of the Air Line subsequently. But I am getting ahead of my story. The Michigan Southern Company only extended to the Indiana State line, a little more than half way from Toledo, or Monroe, to Chicago. It is an interesting fact that all the original companies lost their names except this one. "Michigan Southern" forms a part of the title to-day.

The connecting road under substantially the same (Litchfield) control was the Northern Indiana, to which I will devote a brief space.

NORTHERN INDIANA.

In 1835 a member of the Indiana Legislature, whose friends desired to build a railroad from La Porte to Michigan City, 12 miles, introduced a bill incorporating the "Atlantic & Pacific Railroad." The other members laughed at so pretentious a name, when he, after much argument, came down to "Buffalo & Mississippi" as the title for his 12 mile road, and said he "would not yield another mile." So "Buffalo & Mississippi" was the title adopted.

The corporators met at the house of Col. Stephen Downing, in Elkhart, May 25, 1835, and passed a resolution of inquiry, directed to the Secretary of War, as to what steps, if any, had been taken regarding a survey of a railroad route from Maumee Bay to the Mississippi, under a recent resolution of the United States Senate.

In February, 1837 (the year of our first great financial revulsion), the company was organized, and the following-named gentlemen made directors: Robert Stewart (President), William Barber, Aaron Streeter, John B. Niles and John Brown.

In the Toledo *Weekly Blade* of 1837, may be found the following advertisement:

TO CONTRACTORS:

Notice is hereby given that the grading of the Buffalo & Mississippi Railroad for a double track between Michigan City and La Porte, a distance of twelve miles, will be let at public outcry to the lowest bidder, at La Porte, on Monday, the 14th day of June next.

The maps, profiles and estimates of the route will be ready for examination at the engineer's office in La Porte, after the 1st of June.

MICHIGAN CITY, April 28, 1837. R. STEWART, President.

As the official record shows that this work was let on the day named, and names of contractors, prices, etc., stated, and as the records show considerable complaint by the contractors as to heavy discount on the company's scrip, it puzzled me for a time to ascertain where the contractors put in any work on this twelve miles, but Judge Niles, of La Porte, clears it up as follows: "The location of the road (La Porte to Chicago via Michigan City) was very injudicious, having steep grades and requir-

ing heavy work. About one mile through the woods west of and near La Porte was cleared and partly graded, and can still be seen. Some excavating was also done near the summit, six miles northwest from La Porte, and the strip was cleared through the heavy timber nearer to Michigan City."

But under the pressure of the hard times, the whole enterprise had to succumb. In 1838 may be found the following quaint resolution of the board :

Resolved, That all operations on the road east of Goshen be suspended until the the corps under the direction of Mr. Hardenberg be sufficiently recruited in health to again enter the field, and that they then proceed to locate that part of the road from Goshen to the eastern line of the State.

It may be remembered that 1838 was that dreadful year of sickness and hard times. This enterprise had the life so completely knocked out of it that, during the eight years from 1839 to 1847, even the routine of annual election was neglected. In October, 1847, an effort was made to resuscitate the company, and the following gentlemen were elected directors: William B. Ogden, President; J. Young Scammon, John W. Brooks, Chauncey B. Blair, E. D. Taylor, John B. Niles, A. L. Osborn.

They met and called upon the delinquent stockholders to call and settle. As but one man, and he the owner of two shares, responded, this board "threw up the sponge." Two years later, in October, 1849, Judge Niles and others concluded that having had a fourteen years' struggle with that ambitious title, "Buffalo & Mississippi," and as yet not a foot of track laid, they would try a more modest name, and so organized the Northern Indiana Railroad.

The control passed into the hands of the Litchfields, who were rapidly pushing the Michigan Southern west, and on May 22, 1852, the first train passed over the two roads, the Michigan Southern and the Northern Indiana, from Toledo to Chicago—exactly seventeen years after the little meeting at Colonel Downing's house to organize the "Buffalo & Mississippi."

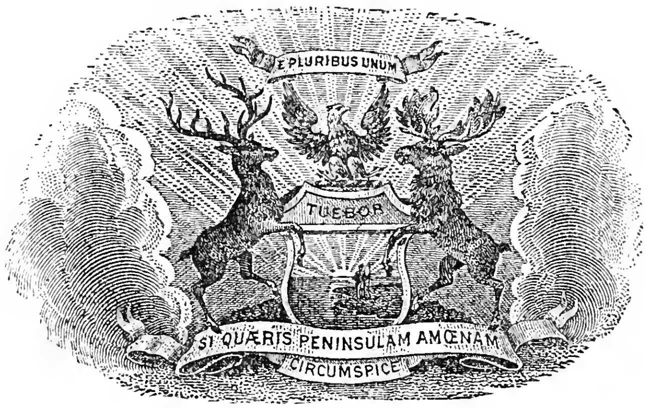
Three years later, in April, 1855, the Michigan Southern and the Northern Indiana were consolidated, and the twenty years' history of the "Buffalo & Mississippi" and its successor—the Northern Indiana—from 1835 to 1855, ended.

This consolidated company, the Michigan Southern & Northern Indiana, was for a time very strong and prosperous, a favorite line for business from the day of its opening, and its stocks and bonds favorites as investments, or for speculation. It paid in 1855 and 1856 ten per cent. per annum to the stockholders. It launched out extensions and improvements, building the Air Line, the Detroit, Monroe & Toledo Railroad, the Jackson Branch and the magnificent steamers "Western Metropolis" and "City of Buffalo," costing $600,000. (They never earned expenses, and were sold after lying idle in Monroe several years, for $50,000.) In fact, the road was too enterprising and was caught with a heavy floating debt by the crash of 1857, its paper going to protest August 19, 1857. For the six years, 1858 to 1863 inclusive, the road not only paid no dividends, but defaulted on all its bonds and was kept busy compromising debts, staving off judgments, etc. "As it never rains but it pours," right in

the worst of this dark period of adversity (June 27, 1859) came the terribly fatal and costly Mishawaka accident. As this accident has a peculiar interest for a body of engineers, I will give you a brief account of it. A very severe rain-storm of several hours' duration accumulated a large body of water in what is usually a dry gorge in summer, between South Bend and Mishawaka, Ind., and carried away a stone arch culvert of 9 feet span, with an embankment of about 20 feet high over it, between 10:30 and 12:30 o'clock at night. The culvert was examined at 10 o'clock and it readily passed the water. The night passenger train from Chicago, with seven cars well filled, running at usual speed in Egyptian darkness, plunged into the gorge. By the crushing of the cars, and by drowning, forty-three were killed outright or died soon afterwards, and sixty were injured. The roadmaster was on the engine and was killed. There was so little water in the gorge next day that a person could step across it.

At one time when the board met in the company's office in New York, they had to borrow chairs from neighboring offices to sit in, as the sheriff had carried off all the company's furniture.

But the war, with its incidental greenback inflation, and feverish



Coat of Arms, State of Michigan.

MOTTO.

"If you wish to see a beautiful peninsula, look around!"

activity in business, came to the rescue in 1861-65, bringing this great property up out of the depths of bankruptcy. Its stock, which was way above par (145) in 1856, sold down to 5 cents in 1860, was again above par (109) in 1863. A most extraordinary and unparalleled fluctuation, in only seven years. From 1863 to 1869 was a period of growth and prosperity, gathering in by purchase the Kalamazoo & White Pigeon, and by lease the Kalamazoo, Allegan & Grand Rapids, and building great depots at Chicago and shops at Elkhart.

In May, 1869, the history of the Michigan Southern and Northern Indiana came to a close by its consolidation with the Lake Shore Railway, forming the present Lake Shore & Michigan Southern Railway.

The Litchfields retired from the control and management the day before the company failed, in August, 1857.

Whatever criticism was made upon their management, one fact was

never disputed. They accomplished wonders in the brief period of one decade, and in the vernacular of the realm, to-day, were "hustlers from Hustlerville."

EAST OF TOLEDO.

While across the base of the great peninsula of Michigan was an obvious and natural route for a railroad, a distance of only 243 miles, from Toledo or Monroe to Chicago—as against about 700 miles of difficult navigation by the great lakes—to build a railroad along the shores of Lake Erie, saving no distance and competing with the great fleet of magnificent steamers that were, in the season of navigation, plying daily, almost hourly, between Buffalo and Cleveland, Sandusky, Toledo, Detroit, thence on to Lake Michigan ports and Chicago, was universally felt, even as late as 1851, to be the silliest possible idea of a few cranks.

In the "forties" the citizens of Erie, Pa., then a little borough of 3,500 inhabitants (Cleveland had but 6,071 in 1840) were watching intently the snail-like progress of the New York & Erie Railroad, which was building very slowly toward Lake Erie.

Its terminus was finally fixed at Dunkirk, which point it reached May 15, 1851, after a struggle of fifteen years.

Railroads were not built as easily then as now. Since that time the construction of railroads has equaled one complete railroad properly equipped from New York to San Francisco (over 3,000 miles) for *each year.*

The great event was celebrated by an excursion train containing President Fillmore, Secretary of State Daniel Webster, and other members of the cabinet, members of Congress and other notables.

The citizens of Erie, in 1846, organized a little railroad company called the Erie & Northeast Railroad, to build a road eastward to the New York State line, only 20 miles, of the same gauge (six feet) as the New York & Erie, with a view of virtually extending that great road beyond Dunkirk to Erie. The intervening gap of 28 miles was to be filled in by another company, called the Dunkirk & State line.

The system of roads in the State of New York, that, in 1853, were consolidated into the New York Central, viewed with alarm this movement in the interest of the New York & Erie, west of Dunkirk.

The Buffalo & State Line, 68 miles, to be laid to the standard gauge of 4 feet 8½ inches, the same as the New York Central system, was started in Fredonia, N. Y., in 1848. It was necessary to get a subscription of $1,000 a mile, or $68,000, before the company could be incorporated. So intense and universal was the conviction that a railroad to compete with Lake Erie would be a miserable failure, it took a year of teasing and drumming by the committee to get this small sum subscribed. Those who did subscribe did it to get rid of the persistent, troublesome committee, and immediately charged their little subscriptions of $100, $500 or $1,000 to "Profit and Loss." Yet no more profitable 68 miles of road was ever constructed in the world than was this.

A prophecy by William Wallace, Chief Engineer, dated March 30, 1850, I quote:

"When this road (the Buffalo & State Line) is completed and connected with the great lines which extend from the lake shore through Ohio and other Western

States, the business will increase beyond all calculations, particularly during winter. It is not unusual at that season to see five stage coaches a day going West at two to four miles per hour, loaded with passengers. With all this in view, who can estimate with any degree of certainty the increase of business that would result from the substitution of the car and iron track for the stage coach ?"

He did not dare to prophesy competition with the lakes.

In 1850, both the Buffalo & State Line and the Dunkirk & State Line roads begun work vigorously on their respective tracks westward to meet the Erie & Northeast, which also was building eastwardly.

As it was evidently foolish to build two roads west of Dunkirk, a compromise was had ; the Buffalo & State Line swallowed the Dunkirk & State Line, and moved over from Fredonia to Dunkirk, and was completed February 22, 1852, with a standard gauge, running up against the Erie & Northeast, which was completed a month earlier (January 19, 1852), with its gauge of six feet. Here was the basis of a big row, as we shall see presently.

CLEVELAND, PAINESVILLE & ASHTABULA.

This city of Cleveland, a favorite lake port with great steamboats coming and going, black with swarms of passengers, was naturally very skeptical as to the utility of a railroad along the shore of the lake eastwardly. She did not move in fact until pushed into it by Painesville, Ashtabula and Geneva.

Books for subscription to stock were opened at different points July 4, 1849, and on August 1, 1849, the first meeting of these subscribers was held at the Weddell House, with General Abel Kimball, Chairman, and Heman B. Ely, Secretary.

A year later (July 26, 1850) a contract was made with Harbach, Stone & Witt to build the road.

As illustrative of the popular conviction of the folly of trying to compete with Lake Erie, I copy the record of the action of the board of directors, dated January 18, 1851.

"Alfred Kelly and H. B. Ely were appointed a committee to make a strenuous effort to get stock subscriptions increased to $500,000, including the $75,000 to be paid to the contractors, and, if necessary, they be authorized to go to New York, but to make no exclusive arrangement with either the New York & Erie or the New York Central unless positively necessary to obtain the subscriptions desired."

In view of the following facts, how odd the foregoing sounds. The road was opened November 20, 1852 ; July 1, 1853, the stockholders were invited to call at the treasurer's office and draw a dividend of five per cent.; six months later the same. And so on for 20 years every six months never less than five, sometimes 8 or 10 per cent.

Panics, hard times, war, pestilence or famine might come, but this road could say with the great apostle, "none of these things move me." It made every original stockholder who stayed in rich. A small stock investment made reluctantly by the city of Cleveland was the basis and chief factor of its great Sinking Fund, one of the financial wonders of the world.

Here then was a line from Cleveland to Buffalo, 183 miles, but right in the middle was the Erie & North East with its gauge of six feet, necessi-

tating two transfers of both freight and passengers, one transfer at Erie, and another at State Line, only 20 miles apart. And yet business was actually done that way for a year. As business increased, this obstruction, like a fish-bone in one's gullet, became intolerable, so on November 16, 1853, a contract was made to change the gauge of this 20 miles to the standard gauge.

For various reasons the city of Erie was violently opposed to this. Hence followed the celebrated Erie war. It lasted from December 7 1853, to February 1, 1854, closing the road between Erie and Harbor Creek, seven miles, over which bleak place passengers had to ride in sleighs, or walk, enduring all the rigors of a severe winter.

A settlement was finally made by which the city of Erie compelled the two roads east of Erie to agree to build the Erie & Pittsburgh Railroad, and the Cleveland road to take half a million stock in the road, then called the Sunbury & Erie, now Philadelphia & Erie Railroad.

On February 1, 1854, the first train passed from Buffalo to Erie, and on to Cleveland over a uniform gauge. On May 15, 1867, the Buffalo & State Line and the Erie & North East railroads were consolidated into the Buffalo & Erie Railroad, and on June 22, 1869, this company was consolidated into the Lake Shore & Michigan Southern, after a history of twenty years of marvelous growth and prosperity. I now come to a brief history of the last link in this chain of road uniting Chicago and the great West to the seaboard cities of New York and Boston.

THE CLEVELAND & TOLEDO.

The Toledo, Norwalk & Cleveland Railroad, a Norwalk enterprise, was organized at a meeting held at the Court House in Norwalk, September 24, 1850. The object of the organization was to build a railroad from Grafton, on the Cleveland, Columbus & Cincinnati Railroad, to Toledo, a distance of 87 miles. This was done rapidly (for those days), the last rail being laid at Monroeville, January 24, 1853. The road was immediately buried up with business, and paid a dividend of five per cent. in July following.

Under the careful, honest management of the president, Charles L. Boalt, of Norwalk, the road was built and fairly equipped for $15,530 per mile, which was $2,500 less than the estimate of the engineer, Mr. Harbach, who made the preliminary surveys.

Mr. G. A. Hyde, of this Club, was the engineer in charge of construction of the western part of this road.

About the same time (1850) a rival road was organized by Judge Ebenezer Lane, of Sandusky, aided by Elyria parties, called the Junction Railroad, to run from Ohio City, via Elyria and Sandusky, to Millbury, 9 miles east of Toledo (with a branch to Toledo), thence on through Perrysburg and Maumee to Swanton on the Air Line of the Michigan Southern & Northern Indiana—a total distance of 134 miles. Only the part from Ohio City to Millbury, 99 miles, was built, although the rest was nearly all graded, and the bridge across the Maumee River, at Perrysburg, was built.

These two roads were consolidated into the Cleveland & Toledo September 1, 1853, which company pushed the construction of the Junction road, or Northern Division, opening it to Sandusky October 24, 1853, and to Millbury, near Toledo, April 24, 1855.

After the crash of 1857, and the resulting depression in business, that portion of the northern division west of Sandusky was abandoned, the superstructure being taken away. While the Cleveland & Toledo Railroad had its ups and downs, like the Michigan Southern & Northern Indiana, it was, on the whole, very prosperous, returning good dividends to its stockholders. The two notable events in its life were the building of the iron bridge across the mouth of the Cuyahoga River, and changing the Eastern terminus of the Southern division, in 1866, from Grafton to Elyria. The Cleveland & Toledo and Cleveland, Painesville & Ashtabula railroads were consolidated in March, 1869, and called the Lake Shore Railway. Two months later this company was consolidated with the Michigan Southern & Northern Indiana Railroad, so in May, 1869, the consolidated Lake Shore & Michigan Southern Railway was born.

The new consolidated company immediately inaugurated an extensive system of improvements. The line between Elyria, O., and Buffalo was double tracked, the abandoned line from Sandusky to Millbury rebuilt, the old project of building the branch south from Ashtabula revived and carried to completion, the branch to Lansing, Mich., built, the Mahoning Coal Railroad to Youngstown built, the Jamestown & Franklin Railroad extended to Oil City. Large purchases of locomotives and cars were made, and other great improvements were contemplated, when came the financial cyclone of 1873, overtaking this road as the crash of 1857 did the Michigan Southern & Northern Indiana, and brought it up all standing. The next four years was a period of great depression—paying up debts, and paying small dividends, under the careful conservative management of Commodore Vanderbilt.

Just a week before his death (January 4, 1877) came that terrible Ashtabula accident, killing outright 92 persons and injuring 64. Only 8 escaped unhurt.

Mr. George M. Reid, Superintendent of Bridges, and an esteemed member of this club, was on this train, but, fortunately, was one of the eight who were not injured. He dragged out of the car his companion, Harvey Tilden, then in charge of water supply, who was stunned and his clothing on fire. An idea of the terrible force of the wind that night may be gained by the fact that the car Mr. Reid was in (the last one), weighing perhaps 35 tons, was blown 75 feet up the valley in falling 65 feet.

When one considers all the destructive elements that entered into a conspiracy against that doomed train, it is a wonder that a single human being escaped from it alive. This accident cost the company directly three-quarters of a million dollars—saying nothing of the large indirect loss by interruption of business, etc.

The same careful, vigorous, clean management inaugurated by Commodore Vanderbilt, was continued by his able son, William H. Vanderbilt, until his death (December 8, 1885), and is being maintained to-day by the latter's sons.

As regards competition, the policy of all these roads has been exactly that which old Polonius advised his son Laertes to adopt: "Beware of entrance to a quarrel, but, being in, bear it that the opposer may beware of thee."

This system has been viciously attacked, in front, in rear, and on both flanks, but it has always made it exceedingly dusty for its assailants, and has fought, defensively, its way to its present position of the leading line between the East and West.

It is a gratifying fact that in all its history of fifty years (1836–1886) this great enterprise was never stronger, more vigorous, physically or financially, than it is now; and there is no room for doubt that long after we are gone and forgotten, it will continue to be an important factor in the welfare of generations yet unborn.

DISCUSSION ON MR. LELAND'S PAPER.

Mr. Leland : The assistant chief engineer of the L. S. & M. S. is here and may be able to give us some information with regard to it.

Mr. G. R. Hardy : Owing to my recent connection with the road the subject is probably more familiar to most of the members of the Club than it is to me. From the present outlook I consider the L. S. & M. S. a magnificent piece of property. With regard to its location in connection with the New York Central it is more favorably situated than any line of which we know at present. As to its grade and alignment, the time is undoubtedly approaching when the gradients will be reduced to the neighborhood of 16 feet as a maximum, with one or two points where perhaps additional power will be used. When you connect that with the New York Central system where they have only an adverse of 78 feet for a short distance, the line may be called a level one. The alignment is wonderful. Between here and Toledo we have some 40-foot grades getting up from the Cleveland station, and also about 25 or 26-foot grades in short sections. East of this place the greatest adverse grades are on the Buffalo Division. On the Air Line Division we shall see most of the work of the coming year in reducing grades ; all but one or two points will be brought down to 16 feet. On the Western Division there is only one place where the grade is such as to require a helper engine ; the other 18 feet grades are being reduced. I used to think that the largest business of the L S. & M. S. was east bound, but since I have become connected with it I find that it has as much business in one direction as another.

Mr. G. A. Hyde : With regard to the Toledo, Norwalk & Cleveland Railroad, I will say that on the 1st day of January, 1851, I commenced at Elmore to locate that portion of the line extending from Toledo to Bellevue, and completed it during the early part of that year. The work of clearing and grading was commenced soon thereafter, and was pushed forward as fast as possible with inexperienced contractors. The roadbed and bridges completed, the track was laid promptly by Chandler, Brown & Company, and the road was opened to public travel in 1858. That portion of the road extending from Toledo to Fremont runs over a level country, and was prepared for the rail for the small sum of $3,000 per mile.

Mr. Leland: Will Mr. Sargent explain why that Michigan line was built from Hillsdale around by Jonesville?

Mr. Sargent : The line from Hillsdale to Coldwater was located by Mr. Hubbard, a brother-in-law of Mr. Litchfield, and its construction was

well under way before I entered upon the road, so I cannot say just what influences were used. Jonesville was an important manufacturing town for the day, and carried quite an influence in the Legislature. The fight between the Michigan Central and the Michigan Southern interests was very fierce, and legislative influence was needed. I am, however, inclined to think that Jonesville furnished a much better outlet from the St. Joseph River Valley than Hillsdale, and better grades and alignment were possible by following up the river to Jonesville than by striking out directly for Coldwater from Hillsdale. But from Coldwater to Chicago the physical features of the country governed the location, and the respondent gained the enmity of some powerful minds by keeping his eye singly on Chicago. He has now the supreme satisfaction of saying that ex-governors, town councils and even the directors of the road could not in the least avail to turn his lines from that foresight. Dollars and time were more precious then than now, and had to be considered, but for the time the alignments and grades of the Michigan Southern and Northern Indiana were remarkable. The charter said we must go to Michigan City, but the maker of the earth said we should go by the way of Boyletown, some forty miles to get twelve, and we went there.

Mr. Searles: I would like to call the attention of the members to that long tangent of the air line and to suggest as a topographical reason for the length of it that it is almost exactly in the line of the axis of Lake Erie produced. Probably at one time the lake extended back to the Indiana line, and that swamp line may once have been the bottom. I would like to inquire what is the general elevation of that long tangent above the present lake level?

Mr. Sargent: It is 400 or 500 feet, perhaps in some places 600. Melburne is about 432. One time in that swamp country I had got down about ten feet when we struck something solid. We excavated and found the skeleton of a mammoth. It was a monster. A remarkable circumstance was that one of the fore legs was worn off quite round The animal must have lost a part of the leg and gone about on the stump.

Mr. Holloway: I think that papers of the kind just presented by Mr. Leland are of great value, as they give the early history of some of the important engineering works of the country, and being printed in the transactions of this Club, they will be preserved for the future, when otherwise they might be lost. The meeting of to-night is a remarkable one, as we have with us some of the pioneer engineers who laid out and surveyed railroads whose names and locations are well nigh forgotten. Among the prominent roads of the State may be named the "Lake Shore," and I have listened with pleasure to what our Member, Mr. Sargent, has said of its early days. While it is well-known that the history of this road can be traced back a good many years, I think few are aware that in one place it was founded on the bones of a mastodon. The traveler of to-day as he rides in the luxurious and swift car, little dreams of the trials and difficulties our engineers have had in wading swamps, cutting through forests, and filling sparkling lakes, as well as sinking bogs in order to obtain the substantial roadbed over which "the limited" now skims so smoothly. While it is contrary to the custom of this Club

to tender a vote of thanks to any of its Members for papers read. I know of nothing in the constitution that will prevent the individual Members present from thanking Mr. Leland for his valuable contribution to the literature of the Club. I would in addition move that Mr. Sargent be requested to formulate his early experience on this road, and present it at some future meeting.

Mr. Leland : Before Mr. Holloway came in I was about to refer to the fact that the early engines on the Lake Shore were, thirty-five years ago, built by the company with which he has so long been connected; they were known among the engineers as "Cuyahogs."

Mr. Holloway : The engines referred to by Mr. Leland were built from plans and under the direction of Mr. Ethan Rogers, one of the earliest, as well as one of the best engineers along these lakes. The peculiarity of Mr. Rogers' locomotives was that they were almost entirely built of wrought iron and steel, and so constructed that they could weave and twist over the rough, uneven and unballasted roads of that early day without breaking down, which I believe the heavy cast iron engines of to-day could not have done. Another peculiarity of the "Cuyahogs" was, that they used an independent steam cut-off valve instead of cutting off by a link, as is now done ; this enabled the engine to start up a heavy load quickly, and to pull it over the line economically. If you should happen to stray about the "round houses," and listen to the tales there told by the old engineers, you would be led to believe that the Cleveland built engines were indeed "Hustlers." A backwoods test was once made between a Cuyahoga engine and an Eastern one as to the economy of fuel. Both engines started from Columbus with exactly the same load and the same quantity of fuel. With careful handling the Eastern engine managed to creep into Cleveland as the last of the fuel was burned out, but the "Buckeye engine," as it reached Cleveland, gave one blast of defiance and then went on to Painesville before it came to a standstill.

HISTORY OF RAILROADS BETWEEN CLEVELAND AND CHICAGO.

BY J. H. SARGENT, MEMBER OF THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read August 9, 1887.]

During the political excitement of "Tippecanoe and Tyler too"—of log cabins and hard cider—forty-seven years ago, when few of the members of this Club were out of their swaddling clothes, or in them for that matter, the old fossil who attempts to address you to-night commenced railroad engineering on what is now known as the Lake Shore & Michigan Southern Railroad.

The ignorance of the "principles and practice" of railroads was in those days profound. There were almost no precedents, and experts were quite as scarce as dollars, which is saying a good deal.

New York had started in to build a road—the New York & Erie—from New York to Lake Erie, and a class of men which would be called to-day a syndicate "log rolled" the Ohio Legislature until they procured the passage of what was called the "plunder law." This law provided that

when certain companies named should have expended a certain sum of money in the construction of their road, the State would loan them a like amount of State bonds.

One of these companies was the "Ohio Railroad Company," chartered to construct a railroad from the State line on the east along the lake to the Maumee River, at Manhattan, below Toledo. The subscribers to this company transferred their farms, town lots and other property (money they had none) to the company in payment of stock. Upon this property money was raised and work in earnest was begun. Finally estimates were fixed up so that the company drew some $250,000 in State bonds. The company had banking privileges, and "Ohio Railroad bills" were as plenty as Canada soldiers in June. Then went up the cry of "plunder," and the Legislature repealed the law, and up went the company, the engineers were paid off in old pile drivers and the road slept the sleep of the just for ten years. The wise ones said this was to be expected, for it was "an insult to the Almighty to build a railroad along Lake Erie."

I will give a brief description of the mode of construction in those primitive days: The road was laid through a very wooden country. West of Sandusky some fifty miles was through an almost unbroken forest plain of heavy timber. Timber was of little worth, so the grade was made of timber, that is, the road was built upon piles, even through the few shallow cuttings. The gauge was six feet and the piles were driven five feet apart longitudinally. The drivers were double, with two hammers and two pairs of leader. The rails were fastened to the bottom of the sills to run on iron rollers placed on top of the piles. A circular saw was hung on a sway bar between the leaders at grade. The piles were delivered along the line on either hand with the butts towards the machine. By means of friction winches and long ropes passing over the head of the leaders they were snatched up and brought to their places with great promptness and precision. When the piles were driven the saw was brought to grade in this wise: The engineers had provided a set of two grade pegs every fifty feet. On two sets of these were placed straight-edges, with another on the saw. By means of screws the sway bar was raised or lowered to bring the top of these straight-edges into the same plane. Then the saw was set in motion and swung right and left, cutting off the piles to grade. Then the wheels or rollers were placed upon them; a drag rope on each side was hooked to the pile and carried through a sheave at the rear and brought forward to the winch.

The engineers had also provided centre stakes ahead and a vertical line in the head of the machine. By means of the two drag ropes, the great machine was easily kept to line. Next followed the tie fitters. The ties, generally of white oak, were made in sectors, split from trees some two feet in diameter and must have a dressed face on the bark side of eight inches; this tie was fitted to the top of the pile, its centre being brought to line. The engineer then pricked off the grade on every fourth tie so as to leave about four inches neck above the top of the pile; wedge shaped gains were then sawed to receive the wooden rails, about nine inches wide. These gains were nicely adzed out to grade with the help of sixteen foot straight-edges; next a two-inch auger hole was bored through the tie

and twelve inches into the pile; then four inches of salt was poured into the hole and a red cedar pin was driven hard upon it. Perhaps the reason why these piles, many of them, after forty years' exposure, are still standing, is that this salt has not wholly lost its savor. The piles had to be not less than ten inches in diameter at the small end. Some of them were split piles, four being made from one cut; this was permitted only where the grade was low. And now the saw-mill gets in its work. These mills were models of simplicity and efficiency. The cylinder was inverted over the saw with the piston attached direct to the muley saw. The rails were eight by nine, and I have known as many as twenty of these rails to be made from one cut. These were sized and keyed into the gains, the nine inches vertical. The saw logs were gathered in at convenient points along the track; always enough to make rails sufficient to reach to the next station ahead. The mill being on wheels was then hauled forward to the next station by oxen. I fear I shall weary you by these particulars, but it is a picture of the past that may never be seen again. The design was to place maple ribbons on top of these rails, upon which iron bars, seven-eighths inch thick, were to be spiked, and to fill in with earth before this superstructure decayed; this was afterward done upon the Sandusky & Mansfield, now Baltimore & Ohio, Lake Division.

I cannot leave the description of the Ohio Railroad without some reference to its Chief Engineer, Cyrus Williams. If not a self-made man, he was a ready-made man. The first I knew of him he was a barn builder in Central New York. While at this calling he stuck an adze into his knee; when the wound healed, he found himself a cripple, for he could not straighten his leg. All undaunted he bought himself a kit of shoemaker's tools and went to pegging his way through the world. A remnant of the Seneca Indians lived in the neighborhood, and one of them seeing Mr. Williams' condition asked the cause; when he learned it he nodded his head and said, "Me cure him, me cure him." The next time he came to town, he brought a bottle of Seneca oil, the modern petroleum, and sure enough a faithful and persistent application of this finally set Mr. Williams on his pins again. From the building of barns he progressed to the building of houses, hotels, court-houses and finally bridges. As the Ohio Railroad from end to end was one continuous pile bridge, Mr. Williams was well fitted to be its chief. As I said he was a ready-made man; but he knew very little about mathematics; so he secured an assistant that did know something about mathematics, but very little else, and the construction went on with vigor as long as there was a shot in the locker. Yes, even longer. Farewell my first love, the Ohio Railroad, you were born a little too soon, as was my last love,—a purified river and an outside harbor. The ghost of the first has arisen in its glory. So may it be with the last.

This was largely a Cleveland project. Its general offices and bank were here as well as some of its chief promoters. The seed then sown fell upon a barren soil. It lacked coin as a fertilizer. Here it rested for some years, while Cleveland was content with her canal boats and lake navigation. Meantime the little town of Sandusky, without state or government aid, was pushing out one line of rails towards Cincinnati

and another towards Newark. While engaged upon this last work, at the request of the Cleveland *Plain Dealer*, I prepared sketch maps of the State, showing what was being done by Sandusky, and that Cleveland might push out towards Columbus and Cincinnati, with estimates of business so very small that I should be ashamed to repeat them to-day, but far too large for the credulity of the age. The seed, however, was sprouting, and men, where enterprise was backed by their dollars, began to open their eyes. The C., C., C. & I. Company was organized, and the same Cyrus Williams and his assistant were placed in the field, and the whole country between Millersburgh on the east and Marion on the west was scoured, and a pamphlet report, with profiles, maps and estimates was made. This took the eye of some New York and Massachusetts men of enterprise, and brought Harback, Stone and Witt to the front and introduced them to the magnificent fortunes awaiting them at Cleveland. There were two parties in the company, one led by the late Governor Alfred Kelly, who desired to carry the road over the hills on the east, and the other by Harback, Stone and Witt, who wished to turn them—the hills—on the west. L. W. Ashley, an imported engineer, was placed in charge of the eastern route, and a native engineer—your humble servant—was called home from Lake Superior, after the snow began to fly in the fall of 1847, and placed in charge of the western route. I took the level myself, with the late General Devereau as rodman. Suffice it to say that the Westerns "got there," and by July, 1849, the rails reached Wellington. When the consummation of this project was assured, the active spirit of Frederick Harback, far too active for the body that supported it, sought other fields to conquer. I have introduced into this paper much of the C., C., C. & I. road as an introduction or stepping stone to the great ultimatum, the Lake Shore & Michigan Southern, to which I will now return.

Mr. Harback formed a combination by which the lazy, sleeping Buffalo & Mississippi Railroad to run from Toledo to Michigan City on Lake Michigan was secured.

In July, 1849, I was withdrawn from the C., C., C. & I. and sent to Laporte, probably for Legislative purposes, and directed to get a grade of twenty feet to the mile from Laporte to Michigan City; but always keeping my right eye on Chicago. Now Laporte is some four miles south of the divide between Lake Michigan and the Ohio River waters, and is several hundred feet above Michigan City, while the two are only about twelve miles apart. An old line had been located and partly graded on a grade of seventy-five feet per mile. I soon found that the twenty-foot grade pointed directly towards Chicago; so I ran my line to Bailytown, twenty miles to the foot of the grade, then turning on an acute angle to the right, I ran back twenty miles more on a perfect plain to Michigan City. This was the main line, and was approved and finally constructed. Next, Goshen was a town out of the way, but had great legislative influence, so I was next sent there to run a line thence to Coldwater, Mich., to connect with the Michigan Southern, which had in the meantime been acquired, and Mr. Hubbard had located and was constructing the division from Hillsdale to Coldwater.

Next, I was sent to locate the Michigan Southern from Coldwater west, still keeping my eye on Chicago. Centerville and Constantine were points in the line; but they were not in my eye. So we secured an engineer from Detroit and put him on this line, while I made for the southern bend in the St. Joseph River at Bristol, and thence on to Laporte. Constantine was out of the line, much to the disgust of General Barra and the ancients, so a four-mile branch was run to that place: and Goshen was ten miles out, and they, too, were appeased by a branch, and I pushed on to Laporte. Then taking up my line at Baily-town, I pushed past the south end of Lake Michigan and run two lines into Chicago: one on the route afterwards occupied by the Pennsylvania road, and the other by the Michigan Central. It was afterwards that the present entrance between the two was determined upon. About these days it was said by some that by means of John Stryker's sweet words and sparkling champagne and Elisha Litchfield's boodle the Legislatures were "fixed," and the "Michigan Southern & Northern Indiana Railroad Company" was born and the Buffalo & Mississippi was laid away to sleep with the Ohio Railroad.

About September, 1850, construction in earnest began, and I was placed in charge of the Michigan Division and Mr. Hubbard of the Indiana Division. In the frost and snows of the winter 1850–51, I was laying track in the Hog Creek woods, reaching Sturgis early in the spring of 1851. We were not troubled with red tape in those days; a visit from the Chief Engineer, new President and some of the directors once or twice a year was all the interference I had with my proceedings. I made my own locations, procured the right of way, let the contracts and paid the bills, money being sent me on my own requisition in crisp New England bank bills. I sent my monthly settlements and vouchers first to Mr. Harback and after that to 14 William street, New York. About this time, there was a new deal—a buy out or a crowd out, I never knew which. A meeting of promotors I will call them was held at Elkhart, to which I was summoned with my plans, profiles, estimates and progress. Here was Geo. Bliss, General Hunt, Charles Butler and F. Harback, Elisha and Edwin Litchfield, John Stryker and John B. Jarvis. I was informed by Mr. Harback that he was out of the concern and that Mr. Jarvis was the Chief Engineer, who desired that I should remain and go on with the work as I was doing; but that I was at liberty to retire with him if I chose. My intercourse with Harback had always been exceedingly agreeable and without the least jar. Still I had become deeply interested in the enterprise and the work and decided to stick and fight it out on that line. From this I went on with the work as before as "Assistant Chief Engineer," reporting results and getting advice from John B. Jarvis in New York. I have often wondered at my temerity in these days, receiving and paying out hundreds of thousands of dollars without even so much as a safe in my office. Once I remember spending the whole day in the field, while ten thousand dollars lay in my trunk unlocked in my room at the hotel. Engineers had to be created in those days. Axemen were turned into chainmen, chainmen into rodmen and rodmen into levelers in rapid succession as they proved their efficiency. On the Indiana Division war

broke out between our road and the Michigan Central. Both parties seemed to think that there was room for but one road into Chicago, and each did its best to keep the other back, resulting in two crossings, and finally in a terribly destructive collision between the two trains at the crossing near Chicago.

All this time the "flat bar" was used from Hillsdale to Monroe and from Adrian to Toledo. As soon as our last spike was driven, at the state line, we repaired to Adrian and rebuilt these roads, substituting the T rail and extending the track from the town of Monroe across the marsh to the mouth of the river, and there built the docks and eating-houses for the palatial steamers, the Northern Indiana and Southern Michigan, the Western Metropolis and the Buffalo, which connected us with the canals and roads of New York Then we moved on to Toledo. In the meantime a third Litchfield and his associates were building the Cleveland & Toledo road terminating on the bank of the Maumee opposite our little station on Water street. Here the business had outgrown the conveniences and enlarged quarters must be provided. The "*middle ground*" was selected as the terminal and I was directed to get there.

A circuitous line crooking around among the streets of the city had been surveyed. I had been accustomed to deal with straight lines, so here again I took the bull by the horns and, starting some four miles out, I struck a tangent so as to clear the bend of Swan Creek and dive under the canal just above the lock, showing a deep blue clay cut for three-quarters of a mile. This project looked large in those days of small things; but the advantages were too obvious to be rejected and the work was undertaken. The middle ground was all under water, the shoalest being four feet. A pile track was driven three-quarters of a mile from the shore to the extreme end of the middle ground. Steam excavators were placed at the cut and this heavy cut of blue clay was transferred to the middle ground to make land, and fourteen acres where the new passenger house now is were acquired for the material with which to complete the filling. The dock line was established at twelve feet water. A tight row of piles was driven and tied back to others, fascines were placed to cover the cracks and the docks were then filled in with clay. The bottom of the middle ground was a rich muck. It inclosed a bayou of stagnant water very prolific of frogs and malaria. Without the help of the divining rod, I had reason to think that we might find, by boring, other water than the Maumee. I drove a foot square box into the mud, the top coming above the water, and bored inside of it sixty feet. Here we struck boulders and coarse gravel, and below them the lime rock, when up came a stream of pure, clean water, with just enough sulphur in it to be distasteful to the "bacteria." This pure fountain had much to do with the health of the engineers and workmen, who had to work in and above the Maumee filth. We were not allowed to interrupt the navigation of the canal, so we built in the winter a temporary aqueduct over our works to carry the canal. Our cut cleared the canal lock but a few feet, and our foundation was lower than that of the lock. When our excavation was well out, a flood came, and the canal took a new departure and sought the Maumee through our cut instead of its own channel. We were forced

to lock the boats down into the Maumee twelve miles above and tow them down to Toledo all one summer, by which time we had completed a double arched culvert or roadway for our tracks. The State forced us to give six feet water-way, so the crown stones of our arches were ten inches deep. Over this we laid in cement a two-inch course of brick. In the midst of it all the cholera broke out with great vigor. East Toledo was entirely depopulated, and from my back office window I saw the freshly-filled coffins passed out of the windows of the houses below. I slept in a bedroom off my office alone. A bottle of cholera medicine by the side of my bed was perfectly effectual without being uncorked. Persistent human effort accomplished its purpose in spite of opposing forces. So this middle ground station was completed, and we got out of the Maumee Valley on a straight line and on a twenty-foot grade. The Island House was built for an eating house and boarding houses for the officers of the road and the train men. It was afterwards turned into a hotel.

In the meantime, Judge Lane. of Sandusky, got possession of the old Ohio Railroad project, and calling it the "Junction Road," worked it through from Ohio City west. It was designed to give Toledo the go-by, passing eight miles south and crossing the Maumee at Perrysburgh, above navigation.

To return to the Ohio Railroad again, I will say that this road, after reaching Sandusky City, turned and ran up the Sandusky bay and river to lower Sandusky, now Fremont, where it crossed the river above navigation, and ran thence straight to Manhattan, four or five miles south of Toledo. Here some young blood from New York, I think somebody's son-in-law, took up the project for extension north. I located this line as far as Monroe. A pile-driver was placed on the work, and many "wild cat" bills were spent upon it. This extension, the "wild cat" bills and bank all went down in a heap with the Ohio Railroad itself. There was another New York Litchfield, a grocer, got the railroad fever, and with Norwalk parties started in and carried through the Cleveland & Toledo road, and Stone & Witt and others pushed on east by the Cleveland, Painesville & Ashtabula road. With these projects east of the Maumee I had nothing to do after the Ohio Railroad went up. Mr. Leland has told us how these and two other lines to Buffalo went to the melting pot and came out the Lake Shore road.

I will now return to the Michigan Southern & Northern Indiana Railroad and tell you what I know of its branches. The surveys of the Tecumseh Branch I extended to Jackson ; but it was built by Mr. Hubbard as engineer. I pushed the Constantine Branch forward to Three Rivers and afterwards the surveys to Kalamazoo. The branch from Jonesville to Lansing was an afterthought, and I had nothing to do with it. The Goshen Branch, ten miles from Elkhart, was built while the main line was building. There began now to be whisperings of another road from Toledo west, and the company determined to forestall it. So I was told to unite Toledo and Goshen by an air line as near as practicable-Bryan, the county seat of Williams County, was the only town in Ohio worth considering. A slight deviation to the south carried us within a half mile of this place, and besides, by this line I could reach an impor-

tant feeder of which for a time I was chief engineer. So beginning at the top of the grade and at the bend of Swan Creek, at what is now Air Line Junction, I planted the transit and setting the first flag ahead, directed the party to fight it out on that line until they heard from me again. On this line they pushed through a dense forest with only here and there a slight clearing, week after week, past Bryan and on to the state line and four miles beyond to a junction with the Eel River Valley road, the feeder mentioned above, a single tangent a degree of the great circle of the earth,—one three hundred and sixtieth of the entire distance around the earth.

On going over this line carefully, I could not find where I could save expense or grade by changing the line or breaking it up, and the road was built on that first line. I am bound, however, to acknowledge that the line is not a straight line. A practical eye will discover when a locomotive is seen four or five miles away that it appears north of the rails near you. The deviation was always in one direction—to the south, and nearly uniform, and I made it quite so when the land was cleared so that I could do so. The line was run with great care, reversing the instrument at all the changes, and passing obstructions by offsets on parallel lines, instead of deflections. If this error had been sometimes to the right and sometimes to the left, it might be laid to carelessness; but being always to the left, the cause would seem to be a constant influence. My explanation is that the observer, when he takes his back sight, is always on one side of the instrument, and when he takes his foresight he is on the other, and his weight upon the elastic earth causes the change. In studying the question, I have only been awakened to this fact, that is if, in middle latitudes you start to run due west and continue a true straight line around the earth, you will come back to your starting point; but it will not be an east and west line in a parallel of latitude, but will be run in a great circle crossing the equator twice on the way.

But to return to our line. This junction I named Butler, after one of our directors, and bought for the two companies a quarter section of land. The Eel River Valley road extended from this point to Logansport on the Wabash over a natural route for a road, reaching Logansport in some four miles less distance from Toledo than by the Wabash Valley road.

The E. R. V. was an independent road; but it was favored by the M. S. & N. I. road, who sent me there as its chief engineer to locate it, and I sent one of my assistants there to build it. The air line was planned as far as that point for a double track, on account of the double business from Chicago and St. Louis it was expected to meet at Butler.

By some sort of occult influence, the directors of the M. S. & N. I. road all at once declined to advance the iron for Eel River, and some of them secured the contract to furnish the iron for the Wabash road, a strictly competing line. The Eel River slept until, many years after, the Michigan Central took it up and carried it to Detroit. When expenditures at Toledo increased, a paymaster was appointed to release me of that part of the work. He was a very worthy man, but he lived at Laporte, was out of health, and must have a clerk. The bills were all paid on my requisitions. The clerk was a smart young man, and had the

custody of the funds. One morning the clerk failed to make his appearance, and could not be found. The safe was locked, and it was supposed that he had on hand some $10,000, with which to pay maturing estimates. When we got the safe open no money or credits were found. Then it came out, as usual, that the young man was fast, and had been in the hands of the gamblers. Some suggested murder, and a report was current that he was seen in New York without a second shirt to his back, and had shipped for the Crimean war; but it was the last of the money or the man. While I had control of the funds, if anything was lost it was not lost to the railroad company.

With the practical completion of the air line my connection with the great enterprise ended. This was in 1854. I had spent five continuous years upon the construction of this great undertaking. It has continued to grow and is still growing. It has lopped off from its name its tail, Northern Indiana, and grafted on its present head, Lake Shore. and has swallowed its neighbor, the Nickel Plate. Its projectors possessed but a few hundreds of dollars, its present owners possess a few hundred millions, and yet not a half century has passed since the honest, quiet, old Quaker, Nehemiah Allen, first dreamed of a railroad along Lake Erie as possible. But neither he nor the most sanguine dreamed that 125,000 miles of railroad in these United States would be built in these fifty years, or that Cleveland would increase in the meantime forty fold—four thousand per cent. Who shall set bounds to the acquisitions of the next fifty years?

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

ENGINEERS' CLUB OF MINNESOTA.

AUGUST 13, 1887:—Regular meeting at Hotel LaFayette, Lake Minnetonka. After supper at 7:30 P. M., the Club was called to order at 9 P. M. Present, President Sublette, W. W. Redfield, J. M. Hazen, Fred Kees, P. B. Winston, R. M. Newman, G. S. Houston, F. W. Cappelen, E. T. Abbott, and W. S. Pardee. Visitors present, W. S. Pearson and A. B. Coe.

The special committee on excursion appointed at last meeting to confer with the members of the St. Paul Club, reported by Mr. Cappelen that the St. Paul Club would prefer to wait until September, and that they would like to go to Chicago at that time. After the reading of the list of standing committees Messrs. E. Chrisman and R. Kendrick were elected to membership.

On motion of Mr. Redfield, the Club tendered a vote of thanks to Mr. G. Sydney Houston for his courtesy in making arrangements for a supper and meeting at Hotel LaFayette, and for the printed badges and other extras furnished on that occasion.

On motion of Mr. Winston, the President appointed a committee of four to ascertain from the heads of city departments, and report to the Club, the relative difference in cost of work done in the city of Minneapolis under the contract sys tem, by day labor, and by the eight hour system.

The Committee appointed were P. B. Winston, R. M. Newman, and F. Kees.

Mr. President suggested to the Committee on Revision of Constitution that this Club be made an incorporated association.

Mr. Cappelen read the first paper of the evening, relative to several recent and appalling disasters. First, with reference to the fall of a wall in the burned building, St. Anthony Elevator Company. He first read extracts from the minutes of the coroner's jury, held on the occasion of the accident. The verdict was that the men killed met their death from the accidental falling of a wall, no person being directly to blame. Mr. Cappelen showed by drawings that the wall against which the wheat pressed was so narrow on its base that the line of thrust was a considerable distance outside the same, and, consequently, the wall could not stand with the weight of wheat against it. Mr. Cappelen thought that the superintendent who had charge of the work of removal of débris should have had more knowledge of the job he was undertaking, and thus have prevented the disaster, also that the coroner's jury rendered an incompetent verdict.

Mr. President read the next paper of the evening, "General vs. Special Legislation for Railroads."

On motion, the paper was ordered printed in the Association JOURNAL.

On motion, the Secretary was ordered to print copies of the paper and distribute among the Members for examination and discussion at the next meeting.

On motion, the Club tendered thanks to the proprietor of the Hotel LaFayette the use of the hotel rooms.

[*Adjourned.*] WALTER S. PARDEE, Secretary.

ENGINEERS' CLUB OF KANSAS CITY.

JULY 30, 1887:—In place of the regular meeting of August 1, the Club took an excursion to Sibley, July 30, where the Chicago, Santa Fe, & California Railway is to cross the Missouri, by invitation of Mr. Octave Chanute, Consulting Engineer of the works. There were, including ladies and other invited guests, 61 in the party.

Leaving the Kansas City Union Depot in a special car at 10:45 A. M. by the Wabash road, the party was joined at the junction with the bridge switch by Mr. J. F. Wallace, Resident Engineer at the bridge, who conducted the visitors to the scene of operations.

After examining the plans and materials, and the arrangements for prosecuting the work, they repaired to the private chair car, where they were served a bounteous and excellent lunch. Subsequently a few of the most adventurous members of the party descended into the caissons, from which they emerged a few moments later drenched and almost exhausted. They declared that the temperature of the outside atmosphere at 97 degrees was wintry in comparison with the temperature (110 degrees) which they experienced during their short stay in the caissons.

In the afternoon the guests were conducted aboard the contractor's steamboat by Mr. Sooysmith, and took a short trip on the river.

They returned by special train to the Union Depot at 7:45 in the evening.

A vote of thanks was tendered to Messrs. Octave Chanute, J. F. Wallace, Charles Sooysmith, and the Wabash Railway Company.

KENNETH ALLEN, Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.

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THE CHANGE OF GAUGE OF SOUTHERN RAILROADS IN 1886.

BY C. H. HUDSON, MEMBER OF THE WESTERN SOCIETY OF ENGINEERS.

[Read June 7, 1887.]

When Horatio Allen recommended a 5-feet gauge for the South Carolina Railroad, he little thought that half a century later an expenditure of over a million dollars would be required to undo his work. He did not expect an extension of the iron rails, within that time, from ocean to ocean, nor that necessities would arise for running cars from one extreme of the country to the other. His successors, in later years, were little wiser. Time, however, has shown that prompt and economical transportation requires that our car, once loaded, shall go to its destination without transfer. To this end, the 6-feet lines attempted to extend their wide gauges to distant centres of trade; while the 4 feet 8½ inch and 4 feet 10 inch gauges tried to compromise their troubles by changing the tread of their wheels from the 3½ inches of the early lines to 5 inches, that they might run on both gauges. This was not altogether satisfactory, and another attempt was made to harmonize matters by the use of a compromise gauge of 4 feet 9¼ inches. This did better, and in time the 4 feet 10 inch, or "Ohio" gauge, was changed to this or its successor, the 4 feet 9 inch. The 5 feet 6 inch gauge became a thing of the past, and the 6-feet either became "standard" or laid a third rail, so that either "wide" or "narrow" trains could be run, and all equipment be kept in use until it was narrowed, when the third rail could be taken up. It became possible to run a car from the Atlantic to the Pacific, north of the Ohio River, and west of the Mississippi River. South of the Ohio and east of the Mississippi, however, the universal gauge, save a few roads, was 5 feet. Interchanges of cars were not thought necessary, and all freight to and from this section had to be transferred from car to car. This burden was realized by both railroads

and shippers, and arrangements were made to exchange trucks, till not a prominent point could be found on the border, without its "hoist" and acres of extra trucks. This was expensive, both in time and "plant," and a change of gauge, which would do away with these "hoists" and the time and labor required to operate them, began to be talked of. Few, however, had the courage to think of it as a thing of the near future.

The Illinois Central Railroad was the first line east of the Mississippi to meet the question and make its southern end conform in gauge to its northern, which it did in 1884, giving a continuous 4 feet 8½ inch line from New Orleans to Chicago.

Under the pressure of competition, the Mobile & Ohio Railroad followed, and in July, 1885, changed to 4 feet 8½ inches.

The most direct competitors of the Mobile & Ohio Railroad, the Louisville & Nashville and Cincinnati Southern systems, saw that they, too, must change, or be at a disadvantage, and determined so to do.

Other large systems realized that they could delay no longer, but must move with the Louisville & Nashville and Cincinnati Southern. The smaller roads had no choice in the matter, but must join the ranks.

At a meeting of the Executive Committee of the Southern Railway and Steamship Association (presidents of the various lines) held in the summer of 1885, a committee of general managers of the principal lines was appointed to take up the matter, formulate plans and fix dates, that there might be harmonious working and the least possible delay and discomfort to the public.

This committee met in New York in October, 1885, but nothing like a general or satisfactory discussion was had. The more the managers looked into the matter, the more they were impressed with its magnitude, and the need for co-operation. Our chairman was requested to call a meeting of the managers of all lines interested, with the request that the heads of their Transportation, Machinery and Maintenance of Way departments be present to aid in the consideration of the questions. This convention was held at Atlanta, Ga., February 2 and 3, 1886, with seventy representatives, of various grades, of thirty roads. Tuesday, June 1st, was fixed upon as the day for the general change, though some six or eight roads, for local reasons, were to change on Monday, May 31st. It was also agreed that branch lines might be changed at such other times as best suited the owners, the general change being so conducted as to best promote the interests of the through lines. Committees were appointed on Transportation, Roadway and Machinery, to discuss in detail matters pertaining to the various departments and to report to the convention for final action.

The matter of the proper gauge to which we should change was taken up by the convention itself, and a lengthy discussion followed. It was urged by one important line, whose business was mostly with Northwestern roads, that 4 feet 8½ inches was the true gauge to be used. The greater parts of the roads changing, however, had their largest interchange of business with the east and northeast, and consequently with the Pennsylvania Railroad system. There must necessarily be a large interchange of cars with that road, and it would follow that the gauge used should readily admit Pennsylvania Railroad cars, and that our cars

must be acceptable to that road. It is true that the Pennsylvania Railroad cars do run on the Northwestern, or 4 feet 8½ inch roads; but it was the experience of several who had worked both gauges, that to haul a given number of cars upon a 4 feet 8½ inch track required more power than upon a 4 feet 9 inch track, because of the greater friction between the wheels and the rails; the flanges in one case clearing the rail by three-fourths of an inch, while in the other the clearance is one-fourth of an inch, and sometimes less, especially when the track men have the track gauged a little too close; not an uncommon thing to find. Again it is not an unusual thing for a wheel to be carelessly put on, and be too wide.

It was the writer's experience, a few years ago, while connected with a 4 feet 8½ inch road, to send some P., Ft. W. & C. cars to the Mississippi River loaded. They were undoubtedly a little too wide and the track in the yard where they went was a little too narrow. The inspector found something wrong, and actually took the trucks out from under the cars and replaced them with narrow trucks, upon which he sent the cars to Chicago, while he loaded the wide trucks upon flats and returned them home in that way.

One road in Ohio, formerly a 4 feet 10 inch "Ohio" gauge, changed to 4 feet 8½ inches, and after a few months experience again changed to 4 feet 9 inches, and found that it was freed from many trials due to small clearance between flange and rail.

It was at last decided that we would make 4 feet 9 inches our gauge. This discussion brought out a special committee on wheel gauge who were to take up that question in connection with other roads of both gauges and report at an adjourned meeting on the 16th of February.

The Transportation Committee reported upon the transportation feature of the problem, which chiefly pertained to the handling of loaded and the return of foreign cars prior to the change, in order that each road might have only its own cars on the day of change, or the fewest possible cars of other roads.

The Machinery Committee treated upon the matter of changing cars from a general stand-point, in order that the work upon those away from home, or upon foreign roads, should be done in the manner desired by the road owning the cars. Beyond that, they left each road to do its own work in its own way.

The Committee on Roadway went more into detail, and based upon the experiences of the Mobile & Ohio, and such other information as they could obtain, reported as follows:

"We are of the opinion that no fixed rules can be adopted to suit all cases; but make the following general suggestions, which we hope will aid all in carrying out the difficult problem which we have to solve.

I.—CHANGE OF GAUGE.

First. On such day or days as shall be designated by the convention, the gauge of the track should be changed from 5 feet to 4 feet 9 inches, by moving in one or both rails, which rail, if but one, to be determined by each road itself.

Second. The entire line between .... and ...... should be changed on ....

Third. The Masters of Roadway on each road should assign the foreman for each section for the days of change, and will issue such detailed instructions to supervisors, in addition to the general orders issued, as may be necessary.

Fourth. Each road should fix its own rate of pay for hands.

II.—PREPARATORY.

First. Supervisors should see that railroad crossings, switch tie bars for split and stub switches, and castings and bolts for Wharton switches, are at the places required five days before the day of change. Foundations for railroad crossings should be examined, and when necessary, new foundations should be framed ready for use on the day of change.

Second. Supervisors should provide each gang foreman with two adzes and on May 1, 1886, preparation of the road bed for the change of gauge should be commenced, to be completed five days previous to the change of gauge. This preparation should consist of adzing the ties to a smooth and even surface with base of rail and clearing any obstructions even with the top of the tie for a space of not less than five inches from the rail that is to be moved in.

Third. Supervisors should also provide every gang foreman with two templates for setting inside spikes, and five days previous to change the work of drawing and setting inside spikes should commence. All inside spikes on the side of the track that is to be changed should be drawn, except the spikes in every third tie on tangents and every other tie on curves and one inside spike at every joint. Spikes should be set with templates in every third tie on tangents and every other tie on curves (not in same ties where inside spikes are left). Spikes should be set straight, and should project above the top of the ties not more than $1\frac{1}{2}$ inches and not less that $\frac{3}{4}$ of an inch under the heads.

Fourth. All spikes drawn from inside of rail and not redriven before the day of change must be straightened and placed on ends of ties in which the inside spikes for change of gauge are driven

Fifth. All roadway forces, where necessary, should be increased not later than thirty days prior to the day of change, so that by the day of change all such forces should be at least double regular number. On day or days of change there should be not less than three men to the mile, each road to divide them into squads to suit itself. On the day of change, service or material trains (engines and cars of standard gauge), should be furnished, said trains to cover that day not more than seventy-five miles.

Sixth. For a section of eight miles, with a gang of twenty-four men, the following tools should be provided:

1 5-feet gauge pole car.
1 standard gauge level car.
10 spike mauls.
10 claw bars.
2 axes.
2 adzes.
2 standard track gauges.
2 track wrenches.
1 water bucket.
1 water barrel.
2 tin cups.
4 extra spike maul handles.
32 kegs spikes.
1 monkey wrench.
2 cleavers.

This list should be increased or decreased proportionately as section is increased or decreased.

Seventh. Meals should be furnished for the forces on day of change by the railroad companies.

Eighth. All track that can be spared from use should be changed previous to the day of the regular change.

III.—ON DAY OF CHANGE.

First. The gangs should reach the position assigned to them at the hour specified on the day of change, and beginning after the last train pas es, which train should be provided with a special signal, to be designated, they should work in the direction designated until they meet, regardless of section limits.

Second. The gauge of main line should be changed first, and afterward the force will return to the various sidings and change them as rapidly as possible, being sure to have their entire work done at sunset, or as much earlier as possible.

Third. The organization on day of change for eight-mile sections should be as follows:

4 men drawing inside spikes.
8 men driving outside spikes.
4 men driving inside spikes.
4 men throwing rail.
1 man with 5 feet gauge pole car.
1 man with standard gauge level car.
2 men extra.

Fourth. An outside spike should be driven in every tie where there was an inside spike previously driven for standard gauge and both should be driven down close to the rails.

Fifth. In changing railroad crossings, the gauge of the crossing road should not be changed unless specially ordered by the Superintendent through the Master of Roadway.

Sixth. In the matter of moving the outer rail on very sharp and long curves, if the rails jam, it is considered that the difficulty can be remedied by throwing the track outward. The amount of this jamming should be ascertained beforehand, and curves should be previously adjusted to prevent jamming on day of change.

IV.—AFTER CHANGE OF GAUGE.

First. Immediately after change of gauge, gangs should proceed to full spike their entire track, drawing and removing all old spikes for that purpose.

Second. The following order should be observed in spiking track after change of gauge:

1st. Spike turnout curves.
2d. Spike main line curves.
3d. Spike bridges and trestles.
4th. Spike main line tangents.
5th. Spike siding tangents.

Third. Foremen should be provided with tickets for paying their men on completion of change, and these tickets should be cashed by the nearest agent on presentation."

Upon February 16, the convention met, pursuant to adjournment, to receive and consider the report of the committee on wheel gauge. This committee sent circulars, upon the subject of wheel gauge, to a large number of roads, both 4 feet 9 inches and 4 feet 8½ inches gauge, in order to get their ideas and experience. At the same time a sub-committee was started upon a tour of investigation, to learn what they could upon the matter. They visited a large number of roads and saw the practical workings, and consulted with the most experienced car builders in the country. After a careful examination of the information thus obtained the committee reported:

"We recommend that 4 feet 5⅜ inches, allowing variations of ⅛ of an inch either way, be adopted as a standard gauge between flanges, and further recommend that the limit gauge of the Pennsylvania Railroad be adopted, that is, the smallest distance between flanges be 4 feet 5 inches, and the smallest distance from out to out of the tread of the wheel be 5 feet 4 inches. Any wheels measuring less than allowed by these limits to be rejected."

This was exactly what the Master Car-Builders had fixed upon as the proper gauge for wheels; but which only stood as a recommendation, never having been accepted as a standard by any roads. The following statement shows the gauge, distance between flanges and lateral play of a number of large systems:

Gauge track. Ft.	In.	Name of road.	Distance between flanges. Ft.	In.	Lateral play. In.
4	9	Pennsylvania	4	5½	¾
4	8½	Illinois Central	4	5⅜	⅜
4	8½	C., B. & Q.	4	5⅜	½
4	8½	L., N. A. & C.	4	5⅜	..
4	8½	N. Y. C. & H. R. R.	4	5⅜	..
4	8½	Missouri Pacific	4	5½	½
4	8½	L. S. & M. S.	4	5¼	¾
4	9	Rich., Fred. & P.	4	5⅜	¾
4	8½	Balt. & Ohio	4	5¼	½
4	8½	C., M. & St. P.	4	5⅜	⅝
4	8½	C. & N. W.	4	5⅜	⅝
4	8½	St. P., M. & M.	4	5⅜	¾
4	9	Ches. & Ohio	4	5½	¾
4	8¾	Pitts. & L. E.	4	5½	¼

It will be seen that the report was based upon the practice of many roads, and would undoubtedly give satisfaction to all. It was adopted by the convention.

The general plan had now been blocked out, and individual work could commence with reasonable assurance that it would be in harmony with that of other roads. The various officers had studied the problem to some extent before the meeting and had worked out many details in their own minds. They were thus enabled to compare notes, and avail themselves of the thoughts of others, gaining much valuable information. Some prepared and printed very elaborate instructions, intending to cover the minutest detail of the work, so nobody could possibly err, only to find that the practical man on the track or in the shop discerned "snags" unthought of by the formulator of the instructions, and also found ways to overcome the difficulties, and in many cases was able to

do his work in a better and cheaper way than was pointed out in the instructions.

The more general way was to print and issue only the general instructions, leaving much for department heads to work out according to the conditions surrounding them. Frequent and full personal consultations were found to be useful. The work was of an extent and character, all things considered, never before undertaken, and must be done at the time selected. There would be no chance to wait and see what others did, or to correct mistakes.

The work of preparation was spread over several months, and in fact was much more of a problem than the mere moving of the one rail three inches. The engines and cars were of varied construction, and the conditions and facilities varied with the various roads and localities. A rule which would work well in one place, would not of necessity be the best in another. A process which would be good upon one road, might not be the most economical in another. So the officers of each line tried to look at their problems, with their surroundings, and decide for himself how much of the general plan they could follow.

I give briefly some of the plans and methods in both track and machinery matters, showing how details were handled.

While several roads had changed gauge, the conditions varied much from these we now had to meet. In former cases there were plenty of neighbors or connections, from whom cars could be borrowed to keep their traffic moving, while in ours everybody had to look out for himself, and could not help his neighbor if he would. We must take care of our traffic and change our cars at the same time. To do this we must withdraw a part of our equipment from service, and change it prior to the change of the track, giving us something to use as soon as the track was changed. Necessarily, this would inconvenience the public somewhat; but there was no other way out of the trouble, though a loss of earnings would follow.

It was argued by some that the proper way would be to provide entire new sets of wheels and axles, so that, at the change, the least possible time would be used in the transfer. The general idea, however, was that it would be very expensive and unwise. When we consider that with 13,000 miles of main track and 1,500 miles of side track, there were 1,800 engines and 40,000 cars, we see the great cost of that plan. 327,000 new wheels and 163,000 axles could not be thought of, even if we did have nearly as many wheels and axles left over to be used in repairs. We must withdraw our cars, and if possible get half of them changed before the first of June.

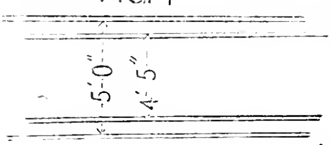
Cars so changed would be "parked" upon tracks, which would be prepared for the purpose, near the shops where the change was made. When the day of change came it would be necessary to gather in all the remaining broad gauge cars at the same points and "park" them upon these tracks, unless the road should be fortunate enough to have a large surplus of broad gauge tracks that were not needed for traffic. Very few Southern roads had this, and the extra tracks were, as a rule, laid A system with 5,000 cars would need about 30 miles.

Just how much would be needed at each point was a matter of con

jecture, as no one could tell in advance how many cars would be changed at any one point, or how many broad gauge cars would be hauled there at the last minute. Storage tracks as a rule could not be built very near the shops where the changes of trucks were made, so that tracks had to be laid connecting them with the shop tracks.

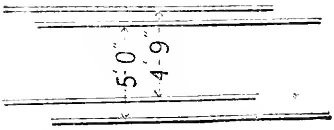
The shop tracks were so arranged that both wide and narrow gauge trucks would run upon them. This was, as a rule, done by putting some guard rails inside the 5-feet track, 4 feet 5 inches out to out, so that the tread of a wheel of the narrow truck would be kept on the rail of the 5-feet track. (See Fig. 1.)

FIG. 1



Some were laid with the outer rails 4 feet 11¼ inches apart, and without guard rail. This, however, did not give good satisfaction, as the bearing surface was so small that a slight imperfection in the rail, or a curve that let the wheel run to one side, would cause a wheel to drop in and give trouble and delay. The tracks from storage yards to shops were sometimes laid with a guard rail (Fig. 1), and at others with two separate tracks on the same ties as shown in Fig. 2.

FIG. 2.



This last was most satisfactory. Several ingenious devices were used to switch from one track to another, all temporary in character and inexpensive. Expensive frogs in same way were avoided, where two tracks or rails were crossed and compound frogs ordinarily used.

In changes heretofore made full sets of bridles for switches had in some cases been provided and "Wharton" switches thrown out, plain stub switches being put in their places. This seemed expensive, and would take up much valuable time on the day of change.

We had various kinds of bridles. The old-fashioned ones for the stub switches, that clasped the base of the rail, as shown in Fig. 3, was cut near its centre and had one end lengthened; each part being at least 2 feet 9 inches long. Three holes were either punched or drilled through the bars near the end, the outer one 2 feet 7½ inches from the inside of the rail head, the next one 3 inches inside of that. This made the bars all alike, and no care had to be used to pick "rights" and "lefts."

FIG. 3.

These were put on the 5-feet gauge by placing the outer hole of one bar over the second hole in the other; a bolt was then put through, a nut put on the bolt, and a spring cotter put in hole which had been drilled through the bolt. Another bolt through the other holes, and the bar was secure. On the day of change the bolts were easily removed, the bars moved 3 inches, the bolts replaced, and our track was 4 feet 9 inches.

FIG. 4

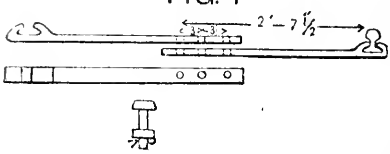


FIG. 5.

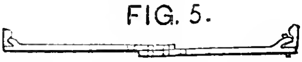
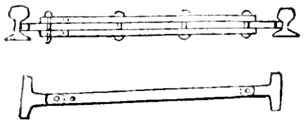


Fig. 4 shows the bars as changed and ready to be put together.

Fig. 5 shows a bar which took hold of the flange of the switch rail, treated in the same way.

Fig. 6 shows another kind, and the manner of its treatment is readily seen by the sketch. A hole is drilled 3 inches back from the one through which the original rivet or bolt was put. The manner of change is readily seen.

FIG. 6



With the "Wharton" there was more trouble, as the bars could not easily be removed to be prepared for change. It was found, however, that a casting could be made that could be placed behind the elevated rail, which would hold it in 3 inches securely, a longer bolt being needed.

FIG. 7

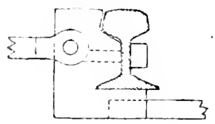
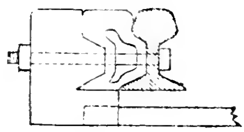
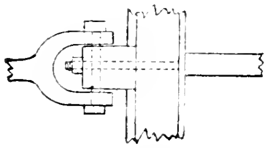


FIG. 8

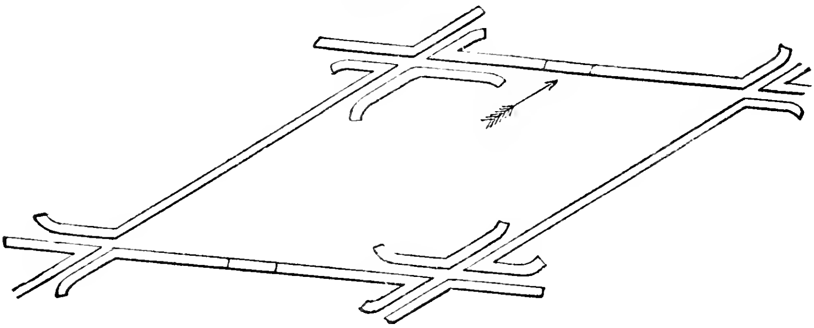




Figs. 7 and 8 show this so plainly that no further description is needed. Five each of these bolts and castings were needed for each switch. The safety throw bar was simply disconnected to be lengthened and replaced at leisure.

Crossings were prepared by cutting out at the centre the requisite length, and then keeping the piece in place by splice bars till the day of change, when the cut pieces were taken out and one side moved up to proper gauge. See Fig. 9.

FIG. 9

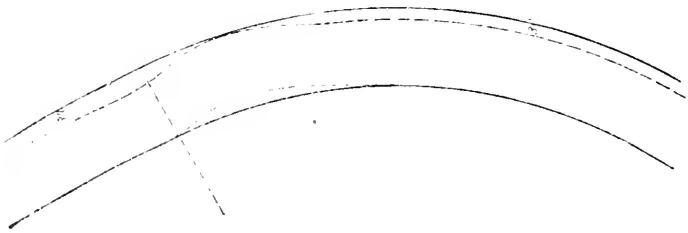


It was decided that the "gauge" rail was the one to be moved. On lines without curves, or with very few, this was undoubtedly correct, but where curves were frequent and long some provision must be made to overcome the "crowding." The committee recommended that the track be thrown out. The tendency of trackmen is so strong to run the tangent into the curve, and so much of our line was curved (45 per cent. upon one division, a large part of the curves being 6 degrees and upward), we felt that we must have some other remedy.

Fig. 10 gives an idea of the plan of the committee. It was claimed that we could cut rails so as to leave room; but our grades were high, and we felt that in the days that would elapse between any such preparation and the day of change our track would "run," as in fact it did constantly. We thought June 1 would be hot, and thus any gap we might calculate upon surely be closed up. All this, of course, where

the outside rail was the one to be moved. It seemed better to us to change sides, and in all cases move the inside rail. To do this we would change the "gauge" rail up to the tangent point the regular 3 inches, the joint first beyond the tangent point (which we will assume at a joint nearest the actual T. P.) we will throw in 2½ inches, while the other rail will come in ½ inch ; the second joint in same way will go in 2 inches.

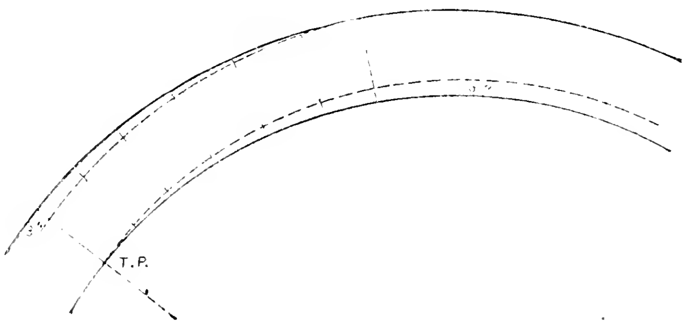
FIG. 10



while the opposite rail comes in 1 inch ; at third joint the distances will be 1½ and 1½ inches ; at the fourth joint, 1 and 2 inches ; at the fifth joint, ½ and 2½ inches ; at the sixth joint our outside rail will not move at all while the inside rail will come in the full 3 inches ; we continue to move the inside rail till within six joints of the next tangent point, when we commence to reverse the process. In the process of preparation spikes have been driven at each of the points mentioned. Fig. 11 shows this plan.

The outside or elevated rail is the one usually used as the line rail upon a curve, so we were following the plan on which we started, viz.: to move the "gauge" rail. The wisdom of the plan was shown when the

FIG. 11



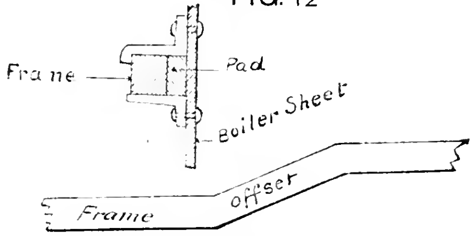
day of change came, and curves changed on this plan were found to be in better line than those changed by any other method. We tried all three plans spoken of.

In the matter of locomotives the conditions varied much. Of the engine builders, the Baldwin Locomotive Works had probably been the most far seeing. For twenty years they had looked forward to this change, and had during that time so constructed their frames and fire-boxes that, by using new driving wheel centres, the change could be made without changing other parts. Few other builders had, until comparatively recently, given the matter any thought, and, as a result many engines were found that could be changed only by moving the

frames in, and not unfrequently the fire-box had to be altered ; this meant a new fire-box and heavy expense. Many engines were thrown out of service by the fact of the great cost of changing them.

The 5-feet engines measured between flanges of drivers (and other wheels as well) 4 feet 8$\frac{5}{8}$ inches. As the gauge was narrowed 3 inches it followed that the new measurement would be 4 feet 5$\frac{5}{8}$ inches, and this in fact was the measure fixed upon by the convention, with a limit of variation of $\frac{1}{8}$ inch either way ; so the frames must be enough less than this from out to out to give a reasonable clearance, or say 4 feet 5 inches. I think all our Baldwins were within this limit : but we found other engines wider from out to out of frames, the frames being set out from the fire-box and a "pad" placed between them. See Fig. 12.

FIG. 12



The "pad" could be cut out and the frame set in against side of the fire-box ; but to do it, this frame had to be offset, as shown in Fig. 12. This was done behind the rocker arm and in front of the pedestal or "jaw," thus rendering unnecessary the changing of machinery, but enabled us to set in the boxes and wheels or tires to the proper width without cutting into the frame.

To get proper information about all the engines, accurate measurements were taken of width of fire-box, width between frames, from out to out frames, between hubs, between inside of tires, between rims of wheels, sizes of boxes and wedges, thickness of hubs, rims of wheels, etc.

Blue print diagrams were prepared upon which were placed all these measurements with the number of the engine. From these the head of the machinery department could see at a glance what was required for each engine.

FIG. 13

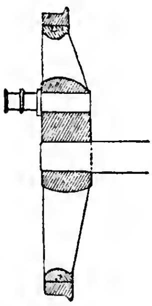
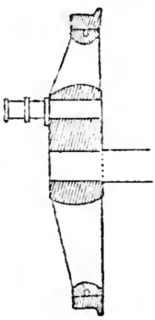


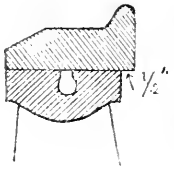
FIG. 14



It was expected at the start that new driving wheel centres would be required for all engines : but examination of our blue prints showed that upon our lines, at least in a majority of cases, this was not necessary. Some few engines, notably some of the old Rogers, had wheels that were dished to such an extent that by pressing them off and putting on again, with the outside face inside, an inch and a half could be gained and the tire could go on as originally placed, squarely upon the wheel. See Fig. 13 as originally, and Fig. 14 as turned.

It was found in practice that a new crank pin had to be put in. In many cases we found that we had thick hubs and heavy flanges to both driving boxes and wedges, so that by taking from $\frac{1}{2}$ to $\frac{3}{4}$ of an inch from the insides of the hubs, and $\frac{1}{8}$ to $\frac{1}{4}$ from the box and wedge flanges, we could gain at least one inch, and in some cases did more. This left not to exceed half an inch for the tire to project over the wheel centre on the inside, neither an unreasonable nor an unusual projection. This

FIG. 15

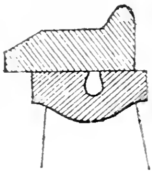


change was a trifling one and done at a cost per engine of \$130.67, including new crank pins.

A new set of wheel centres, finished and in place, including pins. which would probably be needed, would cost \$264.46.

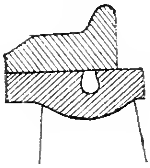
When changes were decided upon, and an engine was in the shop, they were made, and the tires were then put on at the old gauge, projecting outside the centres. They were used in this way without trouble until the day of change came. Fig. 15—Original. Fig. 16—Changed.

FIG. 16



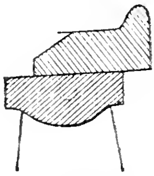
Some of the more recent engines had their wheel centres built expressly with a view to changing. They were placed upon the axle, as would be required with the new gauge; but the rim projected outwardly an inch and a half more than usual, so that the tire could be placed for the five feet gauge and still have its full support. See Fig. 17. When the tire was eventually moved to the narrow gauge this outward rim would be turned off.

FIG. 17



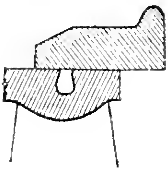
Of course, we were not able to take all our engines into the shop and press in their wheel centres, so had to be satisfied with some temporary arrangements that would give us the use of the engine until such time as it could be taken into the shop. We decided to set tires in leaving the centres unchanged. This gave an inside projection of one and one-half inches plus what little projection there might have originally been.

FIG. 18



When the rim was solid, there was no trouble in this (Fig. 18), provided the tire was not too thin. We fixed upon two inches as a limit of thickness safe beyond doubt.

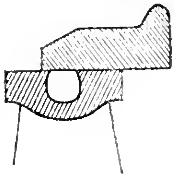
FIG. 19



When the coring was in the middle and not large this was still safe. See Fig. 19.

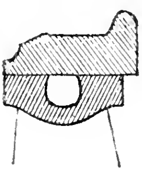
We sometimes, however, found very large cores, and at one side (See Fig. 20). which gave us a very small hold for our tire, and it was not deemed safe for road service. To overcome this danger, we purchased a few new tires 6$\frac{3}{4}$ inches wide, with the outer corner cut away, as shown in Fig. 21. This gave us a bearing over the entire rim of the wheel, and was safe, no matter how large or in what position was the core. The corner was cut off to save material and, at the same time, to save the bad effects of a wide tire upon frogs and switches. The edge was left one inch thick. At some future time when the engine goes into the shop and has new centres put on, or the old ones pressed in, this extra width of tire can be turned off.

FIG. 20



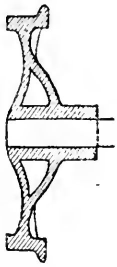
As to engine trucks: The frames had, in many cases, been made of the proper width for the narrow gauge, and the wheels had been built with a heavy hub projecting an inch and a half inward (Fig. 22), so that it would bear against the truck box. It was expected that these wheels would be taken out and one inch and one-half of the hub

FIG. 21



taken off when the change came, so that the wheel could be pressed on the new gauge. This would have taken too much time, so the inch and a half extra hub was left off of all new wheels, but a cast iron collar or washer one and one-half inches thick was placed upon the axle inside each wheel and between it and the box (Fig. 23). When the day of change came a few blows of the hammer upon a cold chisel split this collar off and we were ready to press the wheel the needed inch and a half upon the axle.

FIG. 22



Many of the wheels that were still in use with the long hub were put into a lathe and a groove was cut an inch and a half back from the face, leaving our cast collar, which was easily split off as before. (Fig. 24.)

FIG. 23

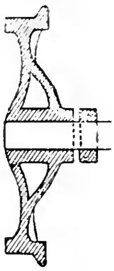


FIG. 24

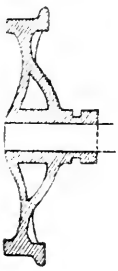
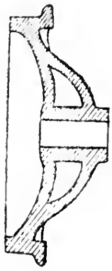


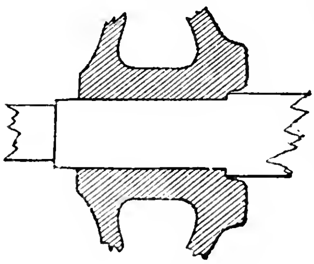
FIG. 25



With tender wheels, as with our car wheels, the case was different. Originally, the axle for the 5-feet gauge was longer than for the 4 feet 9 inch; but latterly the 5-feet roads had used a great many Master Car-Builders' axles for the 4 feet 9 inch gauge, namely, 6 feet $11\frac{1}{4}$ inches over all, thus making the width of the truck the same as for 4 feet 9-inch gauge. To do this a dished wheel, or rather a wheel with a greater dish by $1\frac{1}{2}$ inches than previously used was needed, so that the tread of the wheel could be at its proper place. (See Fig. 25.) There were, of course, many of the wheels with small dish and long axles still in use. Their treatment, however, when the day of change came, did not vary from that of the short axles.

It had been the rule for some years that all axles should be turned back $1\frac{1}{2}$ inches further than needed; but unfortunately the rule had not been closely followed, and many were found not to be so turned. To make the matter worse, quite a number of the wheels were found to have been counterbored about $\frac{1}{2}$ inch deep at the back end, and the axle turned up to fit this counterbore; a good idea to prevent the running in, in case the wheel worked loose, but bad from the standpoint of a change of gauge. In such cases the wheels had to be started off before the axle could be turned back, so that the wheels could be pushed on in their proper position. (Fig. 26.)

FIG. 26



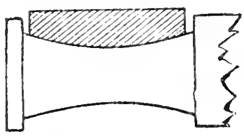
If the work was done where they had a lathe large enough to swing a pair of wheels, they were pressed off but half an inch, the wheels swung in the lathe, the axles turned back $1\frac{1}{2}$ inches, and the wheels then pressed on 2 inches or $1\frac{1}{2}$ inches inside of their first position.

Where no large lathe was in use, the wheels came entirely off before the axles could be turned back. The work in the former case was both the quicker and the cheaper. Where the large lathes were used they were either set down into the floor, so a pair of wheels would easily roll

into place, or a raised platform was put before the lathe, with an incline up which the wheels were rolled and then taken to the lathe. These arrangements were found much quicker and cheaper than to hoist the wheels up, as is usually done.

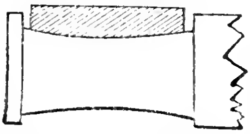
In pressing the wheels on, where the axles had previously been turned back, much trouble was at first experienced because of the rust that had gathered upon the turned part behind the wheel, forming a ridge over or upon which the wheel must be pushed. Some of the roads, at the start, burst 10 or 15 per cent. of the wheels so pressed on. By saturating this surface with coal oil, however, it was found that the rust was easily removed and little trouble was had. It was found, sometimes, that upon axles newly turned back a careless workman would leave a ridge at the starting point of the turning. Frequently, also, the axles were a little sprung, so that the new turning would be a little scant upon one side when compared with the old surface, and upon the opposite side a little full. As an indication that these difficulties were overcome as they appeared, I will say that upon our line only 202 wheels burst out of nearly 27,000 pressed on, an exceedingly small percentage.

FIG. 27



After the change upon the early roads they were troubled for weeks with hot boxes, caused, as we believed, by the changing of brasses. A brass once fitted to a journal will work upon it without trouble; but when placed upon some other journal will probably not fit. If the journal had been worn hollow (and it was surprising to see how many were so worn, the brass would be found worn down to fit it. See Fig. 27. (Exaggerated of course.)

FIG. 28



The next wheel may have an axle worn little or none. See Fig. 28.

Now, if these brasses are exchanged, we have the conditions, as shown in Figs. 29 and 30. and we must expect they will heat. The remedy was simply to keep each brass upon its own journal. To do this the brasses were fastened to the axle by a piece of small wire, and went with it to the lathe and press. When its truck was reached, the brass was there with its journal. Worn out brasses, of course, could not be put in, and new ones were substituted. The little trouble from that source that followed the change showed the efficacy of the remedy.

FIG. 29

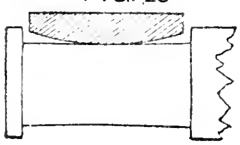
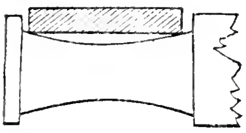


FIG. 30



The manner in which the tires of engines were to be changed, when the final day came, was a serious question. The old fashioned fire upon the ground could not be thought of. The M. & O. had used a fire of pine under the wheel, which was covered by a box of sheet iron, so arranged that the flame and heat would be conveyed around the tire, and out at an aperture at the top. Fig. 31. Many thought this perfect, while others were not satisfied, and began experiments for something better. A device for using gas had been patented, but it was somewhat complicated, as well as expensive, and did not meet with general favor. A very simple device was soon

hit upon. A two-inch pipe was bent around in a circle a little larger than the outer rim of the wheel. Holes $\frac{1}{16}$ inch in diameter and 3 or 4 inches apart were drilled through the pipe on the inside of the circle. To this pipe was fastened another with a branch or fork upon it. To one branch or fork was connected a gas pipe from the meter, while to

FIG. 31

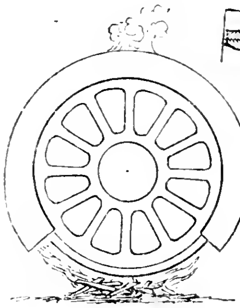
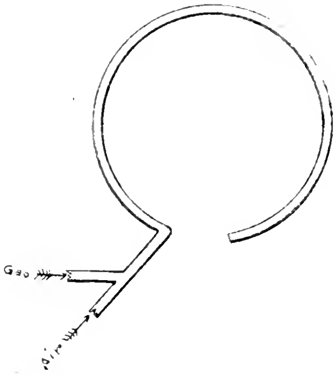


FIG. 32



the other was connected a pipe from an air pump. With the ordinary pressure of city gas upon this pipe it was found that the air pump must keep an air pressure of 40 pounds, that the air and gas might mix properly at the branch or fork, so we could get the best combustion and most heat from our "blow pipe," for such it was. Fig 32.

We were able to heat a tire so it could be moved in ten to twenty minutes, and the machine may be said to have been satisfactory.

Gas, however, was not to be had at all places where it would be necessary to change tires, and the item of cost was considerable.

To reach a result as good, if possible, experiments were begun with coal oil (head light oil). They were crude and unsatisfactory at first, but soon success was reached.

A pipe was bent to fit the lower half of a wheel pretty closely and then turned back under itself about the diameter of the pipe distant from it. This under part had holes $\frac{1}{16}$ inch in diameter and 3 or 4 inches apart, drilled upon its upper side, or under the upper pipe. Connected with the upper pipe at its centre, was a pipe which ran to one side and up to the can containing the kerosene. Between the can and the pipe under the wheel was a stop cock, by which the flow of oil could be controlled. To use the device, open the cock and let a small amount of oil flow; apply fire to the pipe under the wheel, and the oil in the upper pipe is converted into gas, which flows out of the small holes in the lower pipe, takes fire, and heats not only the tire, but the upper pipe, thus converting more oil into gas. We had here a lot of blue flame jets and the same result as with gas, but at less cost. We had

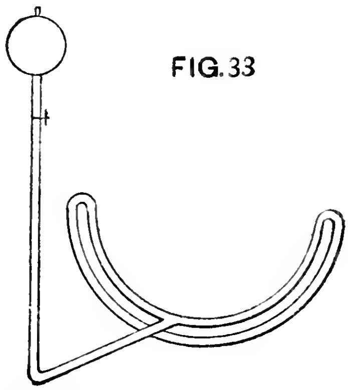


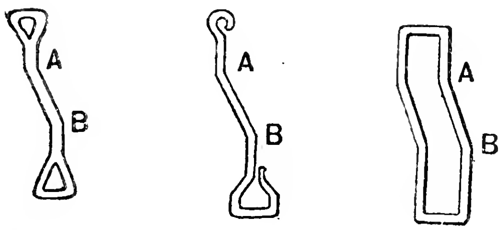
FIG. 33

also a machine that was inexpensive and easily handled anywhere. Boxes were placed over the upper parts of the wheels that the heat might pass closely to the tire. This device was extensively used by our people, and with great satisfaction. In one way care had to be taken, viz.: That in starting the fire it did not smoke and cover the tire with carbon or "lampblack," which is a non-conductor of heat.

Experiments were made with air forced through gasoline, and with oil heated in a can to form gas. There was more danger in either of these than with our blow-pipe device, and no better results were obtained, though the cost was greater.

With the change of the wheels, the brakes had to be changed the same amount, that is, each one set in 1½ inches. This it was thought would either require new hangers, or a change in the head or shoe in some way. We found that the hangers could easily be bent without removal. Figs. 34 show three hangers after passing through the bending process. A short lever arranged to clasp the hanger just below the point A was the instrument; a forked "shore" is now placed, with the fork, against the point A, and the other end against the car sill; press down on the lever and you bend the hanger at A; lower the lever to a point just below B, reverse the process and you have the bend at B; the whole thing taking less than two minutes per hanger. A new bolt hole, of course, has been bored in the brake beam 1½ inches inside the old hole. It takes but a short time after this to change the position of the head and shoe.

FIG. 34



Before the day of change, a portion of the spikes were drawn from the inside of the rail to be moved, and spike set 3 inches inside of the rail. As a rule two spikes were drawn and the third left. At least every third spike was set for the new gauge, and in some cases every other one.

There were several devices with which to set the spike. A small piece of iron 3 inches wide was common, and answered the purpose well.

FIG. 35

FIG. 36

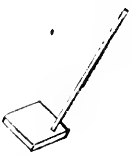


FIG. 37

This had a handle, sometimes small, just large enough for the hand to clasp, while others had a handle long enough for a man to use it without stooping down. See Figs. 35 and 36. Another device is shown in Fig. 37, so arranged that the measurements were made from the head of the other rail. This was liked best, and, it is thought, gave the best results, as the moved rail was more likely to be in good line than when the measurements were taken from the flange.

It was intended that great care should be taken in driving the spike,

that they were in the proper place, square with the rail, and left sticking up about an inch.

The ties, of course, were all adzed down before the day of change.

"Hand-spikes" were originally used to throw the rails, as were lining bars.

We found, however, that small "cant-hooks" were more easily handled and did better work. The first were made like Fig. 38, with a spike in the end of a stick, while the hook was fastened with a bolt about 10 or 12 inches above the foot.

FIG.38

FIG.39

We afterwards made them of an 1¼ inch rod, 3½ feet long, pointed at one end, with a ring shrunk on 1 foot from the bottom. Then the hook was made with an eye, as shown in Fig. 39, which slipped down over the top of the main rod. This was simple and cheap, and the iron was to be used for repair purposes when this work was done.

Upon the system with which the writer was connected we had some branches where we could experiment upon the moving of the rail. Between Selma and Lauderdale the traffic was light, and at Lauderdale it connected with the Mobile & Ohio Railroad, which was narrow, and to which all freight had to be transferred, either by hoisting the cars, or by handling through the house. By changing our gauge we would simply change the point of transfer to Selma. Here was a chance to experiment upon one hundred miles and cause little trouble to traffic. We could see the practical workings of our plans, and, at the same time, leave less to do on the final day. Upon the 20th of April we did this work. It had been our plan to do it somewhat earlier, but floods prevented.

Most of the rail was old chair iron, short, and consequently more time was used in making the change than would have been required had our work been on fish plate rail. Our sections here were about eight miles long, and we arranged our men on the basis blocked out by the committee, viz.: 24 to 26 men to the section, consisting of 6 spike pullers, 4 throwing rails, 12 spikers, 2 to push the cars and carry water.

We soon found 5-feet cars useless and threw them into the ditch to be picked up at some future time.

The men were spread out so as not to be in each other's way, and, when the organization was understood and conformed to, it worked well. One gang changed 5 miles in 5 hours and 10 minutes, including a number of switches. We found, however, and it was demonstrated still more strongly on later work, that after 5 or 6 miles the men began to lag.

We believed we had the best results when we had sections of about that length.

It was arranged that two sections, alternately, commenced work together at one point, working from each other and continuing until the force of another section was met, working from the opposite direction.

The foreman in charge was expected to examine the work and know that all was right. The push car which followed was a good test as to gauge.

A work train was started from each end with a small force (20 or 25

men) to run over the changed track. This train, of course, had been changed on a previous day to be ready for this work.

If a force was overtaken by this train with its work not done, the men on the train were at once spread out to aid in its completion. This done, the train ran on.

Not until this was done was a traffic train allowed to pass over the track. The same rule was followed upon all the work.

Upon the final day it was required that upon all high trestles and in tunnels the track should be full spiked before being left, or a train let over. This took extra time and labor, and possibly was not necessary; but it was a precaution on the side of safety.

Upon the day of the change of the Alabama Central Division (Selma to Lauderdale), superintendents of other divisions, with their road masters, supervisors, master mechanics and many section foremen, were sent over to see the organization and work and the preparations that had been made. Many of them lent a helping hand in the work. They saw here in practice what had only been theory before.

About a week before the general change that portion of the road between Rome, Ga., and Selma, Ala., about 200 miles, was changed, and again men from other divisions were sent to see and aid in the work ; so when the final day came the largest possible number of men were able to work understandingly.

On the last day of May the Memphis & Charleston, Knoxville & Ohio, and North Carolina Branch were changed, and on June 1 the line from Bristol to Chattanooga and Brunswick.

Other roads changed their branch lines a day or two before the 1st of June ; but the main lines, as a rule, were changed on that day.

It was no small matter to take care of the cars and arrange the train service so there should be no hitches. It was not expected that connections would move freight during the 48 hours prior to the change, and these days were spent in clearing the road of everything, and taking the cars to the points of rendezvous. All scheduled freight trains were abandoned on the day prior to the change, and only trains run *to* such points.

Upon the East Tennessee system these points were Knoxville, Rome, Atlanta, Macon, Huntsville and Memphis, and to these points all cars must go, loaded or empty, and there they were parked upon the tracks prepared for the purpose. Passenger trains were run to points where it had been arranged to change them, generally to the general changing point.

Most of the southern roads have double daily passenger service ; upon all roads one of these trains, upon the day of change, was abandoned, and upon some all. Some, even, did not run till next day.

We were able to start the day trains out by 10 o'clock or 11 o'clock A. M., and put them through in fair time. Of course, no freights were run that day, and the next day was used in getting the cars which had been changed out of the parks and into line. So our freight traffic over the entire South was suspended practically three days.

The work of changing was to commence at 3:30 A. M., but many of the

men were in position at an earlier hour and did commence work as soon as the last train was over, or an hour or so before the fixed time. Half-past three A. M., however, can be set down as the general hour of commencement.

For five or six hours in the cool morning the work went on briskly, the men working with much more than ordinary enthusiasm ; but the day was warm, and after 9 or 10 A. M. it began to lag. All was done, however, before the day was over, and safe, so that trains could pass at full speed.

The men all received $1.50 for the work, whether it was finished early or late in the day, and were paid that afternoon as soon as the work was done. Tickets wore given the men, which the nearest agent paid, remitting as cash to the treasurer.

On some lines it was deemed best to offer prizes to those who got through first.

Reports showed some very early finishes ; but the facts seem to have been that under such encouragement the men were apt to pull *too many* spikes before the change and put *too few* in while changing. They were thus reported through early, but their work was not done, and they took great chances.

It was by most considered unwise to offer such prizes, preferring to have a little more time taken and be sure that all was safe. Such lines seemed to get their trains in motion with as much promptness as others. This, with freedom from accident, was the end sought.

It was found after the work had been done that there had been little inaccuracies in driving the gauge spike, to which the rail was thrown, probably from various causes. The rail to be moved may not always have been exactly in its proper place, and then the template in the hurry may not have been accurately placed, or the spike may have turned or twisted.

Whatever was the cause, it was found that frequently the line on the moved side was not perfect, and, of course, many spikes had to be drawn and the rail lined up and re-spiked. The more careful the work had been done, the less of this there was to do afterwards. With rough track this was least seen. The nearer perfect, the more noticeable it was.

Of course, we all planned to get foreign cars home and have ours sent to us ; but when the interchange stopped, we found we had many foreign cars, which, of course, had to be changed. This subject had come up in convention and it had been voted to charge $3 per car when axles did not need turning, and $5 where they did. By comparison with the cost of changing, as shown in this paper, it will be seen that to our company, at least, there was no loss at these figures.

The tables on the following pages will explain the work done upon the Louisville & Nashville, and East Tennessee, Virginia & Georgia systems.

It is to be regretted that the writer has not at hand information regarding other roads that fuller statements and comparisons might be made and the showings be of greater value.

The figures of the Mobile & Ohio are added, having been compiled from the annual report of that road.

MOBILE & OHIO RAILROAD.

(*Compiled from Annual Report.*)

	Number changed.	Cost of labor.	Cost of material.	Total cost.	Average cost.
Engines and tenders......	47	$8,031.42	$7,276.86	$15,308 28	$325.70
Pass., bag. and ex. cars...	55	438.37	104.25	542.62	9.87
Freight cars, 1,361..... Freight trucks, 107½..	1,468½	5,719.03	739.57	6,458.60	4.40
Lever and push cars.....	143	1,427.55	476.93	1,904.48	13.32
	Miles.				
Track (including sidings).	583.5	17,109.53	7,275.14	24,384.67	41.79
Bridges..................	583.5	1,896.60	190.00	2,086.60	3.58
Track tools........	583.5	170.72	1,405 74	1,576.46	2.70
Shop tools...............	583.5	419.70	2,982 90	3,402.60	5.83
Temporary side tracks...	12.09	1,958.94	372.37	2,331.31	192.83
Switching cars..........	.....	1,398.18	16.50	1,414.68	....
Car hoists..............	......	2,499.38	4,419.34	6,918.72	....
Total cost............	......	$41,069.42	$25,259.60	$66,329.02	....
Total average cost per mile...					$113.68

LOUISVILLE & NASHVILLE RAILROAD.

(*Compiled from Annual Report.*)

Miles of track—Main line....	1,893.7		
—Side track..............	196 3		
		2,090.0	
Track.		Total.	Cost per mile.
Section labor—Before day of change...	$28,106.60		
—On day of change......	20,090.42		
—After day of change.....	19,713.19		
		$67,910.21	$32.49
Carpenter labor..		3,799.19	1.82
Spikes..		20,873.70	9.99
Switches................................		6,331.85	3.03
Tools...................................		2,749.50	1.31
Hand cars and sundries.................................		5,691.39	2.72
Total..		$107,355.84	$51.36

Equipment.

	Number.	Total.	Average cost.
Locomotives................................	264	$53,480.98	$202.58
Cars (300 of these passenger—3.5%)...........	8,537	49,577.20	5.81
Total cost.........................		$210,414.02	
Total average cost per mile.........			$100.67

EAST TENNESSEE, VIRGINIA & GEORGIA SYSTEM.

	Number changed.	Cost of labor.	Cost of material.	Total cost.	Average cost.
Engines and tenders......	180	$8,227.47	$2,904.30	$11,131.77	$61.82
Pass., bag. and mail cars..	168	734.93	59.67	794.60	4.73
Freight cars and cabooses.	5,175	17,425.57	1,224.08	18,649.65	3.60
M. of W. cars............	439	2,038.44	549.47	2,587.91	5.89
	Miles track.				
Track (inc. sidings).......	1,532.7	27,718.17	40,912.09	68,630.26	44.78
Bridges..................	1,532.7	1,808.57	200.00	2,008.57	1.31
Track tools......	1,532.7	194.48	2,573.83	2,768.31	1.80
Storage tracks, inc. taking up....	37.02	9,825.41	1,481.59	11,307.00	305.44
Shop tools..........		472.20	2,728.30	3,200.50	......
Total cost		$68,445.24	$52,633.33	$121,078.57	......
Total average cost per mile					$79.06

Axles condemed	577
Wheels condemned	754
Wheels burst	202
New axles used	1,102
New wheels used	2,783
Axles turned back	8,316
Wheels pressed on without turning axle	23,952
New brasses used	10,723
Cars narrowed (not including lever or push cars)	5,343
Engines narrowed	180
Average cost of new centres and crank pins, etc	$264.46
Average cost of cutting off hub and pressing wheels and new pins	130.67
Average cost of pressing old tires on old centres	29.08
Average cost of pressing old tires on broad centres	31.83
Average cost of labor putting on new tires	22.94

COMPARATIVE STATEMENT OF AVERAGE COST OF VARIOUS ITEMS OF WORK.

	M. & O. R. R.	L. & N. R. R.	E. T., V. & G. R. R.	Average.
Engines and tenders—per engine	$325.70	$202.58	$61.82	$196.70
Pass., bag. and ex. cars—per car	9.87	*5.81	4.73	6.80
Freight cars, per car	4.40	†5.81	3.60	4.60
M. of W. cars, per car	13.32	2.72	5.89	7.31
Track (inc. sidings, bridges, etc.), per mile	45.37	47.33	46.09	46.26
Track tools, per mile	2.70	1.31	1.80	1.94
Temporary side tracks per mile	192.83	....	305.44	249.13
Total per mile of track, inc. sidings	$113.68	$100.67	$79.06	$97.80

* Expense not divided as between passenger and freight cars.
† 3.5 per cent. passenger, baggage and express cars; 96.5 per cent. freight cars.

NOTE.—Since the preparation of this paper the general manager of the Norfolk & Western Railroad has kindly furnished the following items of expense for that line.

	No.	Cost.	Average cost.
Engines and tenders	95	$37,730.00	$397.16
Cars (all kinds)	3,615	37,994.65	10.51
Track, miles (including sidings)	597.5		
Labor		25,296.96	
Tools and supplies		3,531.12	
Changing M. of W. equipment		813.13	
Switches		571.67	
Spikes		8,508.22	
Total track		$38,721.10	64.80
Total		$114,445.75	
Total average cost per mile			$191.53

And the superintendent of the S. F. & W.R. R. has also furnished the expenses for that road.

	No.	Average cost.
Engines and tenders	75	$76.31
Cars (passenger)	95	4.67
" (freight)	1,133	3.88
Track, including sidings	601.76	44.49

Nothing was said about shop or other tools, storage tracks, or changing of maintenance of way equipment.

COMPARATIVE STATEMENT OF AVERAGE COST OF LABOR OF VARIOUS ITEMS OF WORK.

	M. & O. R. R.	L. & N. R. R.	E. T., V. & G. R. R.	Average.
Engines and tenders..	$170.88	Not divided.	$45.71	$108.29
Pas., bag. and ex cars	7.97		4.38	6.17
Freight cars.........	3.89		3.36	3.62
M. of W. cars........	9.98		4.64	7.31
Miles track (inc. sidings, bridges, etc.).	32.57	34.31	19.26	28.71
Track tools per mile.	.30	Not	.13	.21
Temporary tracks....	162.03	divided.	265.40	213.71
Total per mile of track............	$70.38	Not divided.	$44.72	$57.55

COMPARATIVE STATEMENT OF AVERAGE COST OF MATERIAL OF VARIOUS ITEM OF WORK.

	M. & O. R. R.	L. & N. R. R.	E. T. V. &. G. Ry.	Average.
Engines and tenders..	$154.82	Not divided.	$16.11	$85.46
Pas., bag. and ex. cars	1.90		.35	1.12
Freight cars.........	.51		.24	.37
M. of W. cars.	3.34		1.25	2.30
Miles track (inc. sidings, bridges, etc. ..	12.80	13.02	26.83	17.55
Track tools, per mile.	2 40	Not	1.67	2.03
Temporary tracks...	162.03	divided.	40.04	101.03
Total per mile of track............	$43.30	Not divided.	$34.34	$38.82

SUMMARY OF STATEMENTS OF L. & N. AND E. T., V. & G. RAILWAYS.

The mileage changed of the L. & N. and E. T., V. & G. systems combined aggregates..................	3,622 miles.
The total cost of these two roads..................	$331,492.59
Or an average per mile of..................	91.52
Total miles changed was about..................	14,500 miles.
Which would give total cost, at same rate..................	$1,327,040

We should really add to this a large sum for the great number of new locomotives which were purchased to replace old ones that could not be changed, except at large cost, and which, when done, would have been light and undesirable.

Upon the basis of the work done upon the L. & N. and E. T., V. & G. systems, which combined, cover about one-fourth the mileage changed, we have made the following estimates, which will perhaps convey a better idea of the extent of the work than can be obtained in any other way.

Miles of track changed, about..................	14,500
Locomotives changed, "	1.800
Cars (pass. and freight) changed, about..................	45,000
New axles used, "	9,000
New wheels used, "	20,000
Axles turned back, "	75,000
Wheels pressed on without turning axles, about..................	220,000
New brasses used, about..................	90,000
Kegs of spikes used, about..................	50.000
Cost of material used, about..................	$600,000
Cost of labor, abcut..................	730,000
Total cost of work, about..................	1,330.000
Amount expended on equipment, about..................	650,000
Amount expended on track, about..................	680,000
Amount expended on track on day of change in labor, about..................	140,000

The work was done economically, and so quietly that the public

hardly realized it was in progress. To the casual observer it was an every-day transaction. It was, however, a work of great magnitude, requiring much thought and mechanical ability.

That it was ably handled is evidenced by the uniform success attained, the prompt changing at the agreed time, and the trifling inconvenience to the public.

EXPERIMENTS WITH SUBMERGED AJUTAGES.

By C. W. Clark, Member of the Engineers' Club of St. Louis.

[Read April 20, 1887.]

The experiments treated of in this paper were made by request of Prof. S. W. Robinson several years ago in the physical laboratory of the University of Illinois, and at that time were supposed to be the most complete experiments of the kind recorded. The co-efficients of discharge, etc., were computed soon after the experiments were made, but were laid aside until recently without being put in proper shape for publication. One feature of these experiments, so far as I know, is unique—that is, the measurement of the decreased pressure on the inner walls of the ajutages during the flow of water through them.

The experiments are limited to one form of orifice or mouthpiece and four forms of ajutages. Three of these ajutages, however, were made in sections, so that different lengths of each form were used. Unfortunately some of the data taken was lost, and a more extended series of observations is necessary for making a thorough discussion of the forms of ajutage experimented with. I present, however, such results as I have obtained, hoping that they may be of some interest and possibly of some practical use to the hydraulic members of our Club.

The following experiments were made, the first two being preliminary to the experiments with the ajutages :

1st. Twenty observations were made for determining the co-efficient of discharge of a mouthpiece made of nearly the form of the *vena contracta* (section shown in Fig. 1).

2d. Ten observations were made for determining the co-efficient of discharge of the same mouthpiece when submerged.

3d. Nineteen observations were made for determining the co-efficient of discharge of three different lengths of the ajutage, when submerged (shown in Fig. 2) ; also for comparing the discharge of the ajutage with the discharge which the simple mouthpiece would give if working with an added head equal to the water equivalent of the manometer reading, which measures the decreased pressure on the inner walls of the ajutage.

4th. Eighteen observations were taken for similar determinations for three lengths of the ajutage when submerged (shown in Fig. 3).

5th. Thirty observations were made for similar determinations for five lengths of the ajutage (shown in Fig. 4).

6th. Six observations were made for similar determinations for the ajutage shown in Fig. 5.

Each ajutage had a hole drilled through its side near the junction with the mouthpiece, in which was inserted a small tube for connecting with

a rubber hose leading to one arm of a manometer; a second rubber hose connected with the other arm and had one end submerged in the receiving tank. These rubber hose were filled with water. The diminution of pressure in the ajutage during the flow through it is thus measured by the height to which the atmospheric pressure raises a column of mercury in the manometer. This column of mercury reduced to a water equivalent gives the, so called, added head.

The discharging tank was nearly a rectangular prism of 1 square foot section, and the receiving tank was nearly a rectangular prism of section 1 foot by 2 feet. The discharging tank, before an observation, was filled full and a gate covering the orifice was opened, at the instant the surface reached a certain fixed point time was taken and the manometer was read, and again the time taken and manometer read at the instant the surface reached a second fixed point. A knife edged hook gauge was used to show the exact instant that the surface reached these points. The heads for these points were very carefully determined. The volume of the discharging tank between these heads was found by making careful measurements of many elements of the end and middle areas of the prism and computing by the prismoidal formula. The area of the orifice was found by making several micrometric measurements of three diameters, 60 degrees apart. The above measurements are all that was necessary for the first experiment, but for the other experiments the head in the receiving tank had to be known at the beginning and end of the observation. The difference of heads in the receiving tank compared with the difference of heads in the discharging tank gave the relative cross section of the tanks. In experiments 2–6 inclusive, a given quantity of water was used, then the time of discharge being noted and the quantities above noticed being measured, we have all the necessary data for determining the co-efficients of discharge. The decimeter was used as the unit of measure.

The formulæ used for the reductions will be briefly noticed before giving the tables of data and results. The so-called theoretical formula for discharge through a circular orifice in a thin plate is

$$D = a\,t\,\sqrt{2\,g\,h} \qquad (1)$$

where D is the volume of discharge, a is the area of orifice, t is the time of discharge, g is the force of gravity and h is the constant head. This theoretical value of D is too large and it has been shown by experiment that we must multiply the second term of equation (1) by a co-efficient of contraction $C_c = 0.631$, and by a co-efficient of velocity $C_v =$ 0.975; the product of these co-efficients is the co-efficient of discharge $C_d = 0.615$, hence the formula used in practice is

$$D = 0.615\,a\,t\,\sqrt{2\,g\,h} \qquad (2)$$

If instead of an orifice in a thin plate we use a mouthpiece of the form of the vena contracta we eliminate C_c from the formula and multiply only by C_v. If the orifice is submerged we have

$$D = C_d\;a\;t\,\sqrt{2g\,(h - h')} \qquad (3)$$

h and h' being the heads in the discharging and receiving tanks respectively and being constant.

If the tank is discharging freely without receiving, the head becomes

variable. The discharge for a differential time is represented by $A\ d\ h$—where A = area of cross section of tank—and also by $C_c\ a\ v\ d\ t$—where v is the velocity per second, therefore

$$A\ d\ h = C_c\ a\ v\ d\ t = C_d\ a\ \sqrt{2\ g\ h}\ d\ t \text{ or } d\ t = \frac{A\ d\ h}{C_d\ a\ \sqrt{2 g\ h}} \quad \text{which}$$

integrated between limits of h and h_1, gives, by transposing

$$C_d = \frac{2\ A}{t\ a\ \sqrt{2\ g}} (\sqrt{h} - \sqrt{h_1},) \tag{4}$$

This is the formula used for computing the co-efficient of discharge for the first experiment.

Where the orifice is submerged and the discharge takes place freely from a discharging to a receiving tank, the effective head is changing by a decrease of head in the discharging tank and an increase of head in the receiving tank. If h and h_1 represent respectively the heads at beginning and end of observation in the discharging tank, and h' and h_1' the same in the receiving tank, the effective head at beginning is $h - h'$ and at end is $h_1 - h_1'$. The discharge for a differential time is

$$A\ d\ h = B\ d\ h' = C_c\ a\ d\ t\ v = C_d\ a\ d\ t\ \sqrt{2\ g\ (h - h')}$$

where B = area of cross section of receiving tank. From this equation we have

$$d\ h = \frac{B\ d\ h' + B\ d\ h}{A + B} = \frac{B\ d\ (h - h')}{A + B}$$

by substituting above and transposing

$$d\ t = \frac{A\ B\ d\ (h - h')}{(A + B)\ C_d a\ \sqrt{2\ g\ (h - h')}}$$

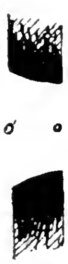
integrating between limits of $(h - h')$ and $(h_1 - h_1')$ and transposing we get

$$C_d = \frac{2\ A\ B}{(A + B) t\ a\ \sqrt{2\ g}} (\sqrt{h - h'} - \sqrt{h_1 - h_1'}) \tag{5}$$

This is the formula used for computing co-efficients of discharge for experiments 2–6 inclusive.

EXPERIMENT NO. 1.

No. of obs.	$t' - t$. m.	s.	No. of obs.	$t' - t$. m.	s.
1	1	03¼	8	1	03
2	1	03	9	1	02¾
3	1	03¾	10	1	03¼
4	1	03	11	1	03
5	1	03	12	1	03
6	1	03½	13	1	03
7	1	03¼	14	1	03¼
			15	1	02¾
		63.25	16	1	02¾
			17	1	03¼
			18	1	02¾
			19	1	02½
			20	1	02½
					62.904



Remarks.—The figure shows a section through the plate containing the orifice used in this experiment. It shows the diam. (0) of the orifice, natural size, and also gives the form of the orifice.

When these obs. were made the tanks were leaking, and the correction for leakage for obs. 1–7 inclusive, is different from the subsequent obs., and hence in the computations they are worked up separately. t = time at beginning and t' = time at end of observation.

After applying all corrections, the following values for quantities entering the formula were found:

For obs. 1–7, $t' - t$ = 63.25 sec.; h = 10.00775 dec.; h_1 = 8.01475; a = 0.0070882 sq. dec.; A = 8.95034 sq. dec.; g = 98.0213 dec.

For obs. 8–20, same as above, except $t' - t$ = 62.904 sec., and h = 8.01175 dec.

EXPERIMENT NO. 2.

No. of obs.	$t' - t$. m.	s.	No. of obs.	$t' - t$. m.	s.
1	1	09	7	1	08½
2	1	08¾	8	1	08¼
3	1	08½	9	1	08½
4	1	08½	10	1	08⅓
5	1	08			
6	1	08	Mean		68.45 sec.

Remarks.—The same orifice is used here as in Experiment No. 1, but it is here submerged.

The values to be substituted in the formula for this case are as follows (all necessary corrections having been applied):

$t' - t = 68.45$; $h = 9.98625$; $h_1 = 8.01575$; $h' = 0.84625$; $h_1' = 1.81125$; $a = 0.0070882$; $A = 8.98274$; $B = 18.43556$; $g = 98.0213$.

EXPERIMENT NO. 3.

Set	No. of obs.	$t' - t$ m.	s.	Manometer r'dg at time t. dec.	Manometer r'dg at time t'. dec.
3	1	0	36	1.97	1.30
	2	0	37½	1.95	1.10
	3	0	36	1.85	1.30
	4	0	37	1.80	1.05
	5	0	36	1.80	1.30
	6	0	37	1.90	1.28
	Means		36.58	1.878	1.222
2	1	0	36	1.80	1.07
	2	0	36½	1.73	1.18
	3	0	36¾	1.77	1.22
	4	0	37½	1.65	1.10
	5	0	35¾	1.80	1.10
	6	0	36½	1.75	1.20
	Means		36.5	1.75	1.145
1	1	0	38¾	1.55	1.00
	2	0	38	1.40	0.95
	3	0	38½	1.45	0.90
	4	0	38½	1.45	1.05
	5	0	38	1.50	1.00
	6	0	39	1.40	1.00
	7	0	39½	1.40	0.93
	Means		38.6	1.45	0.976

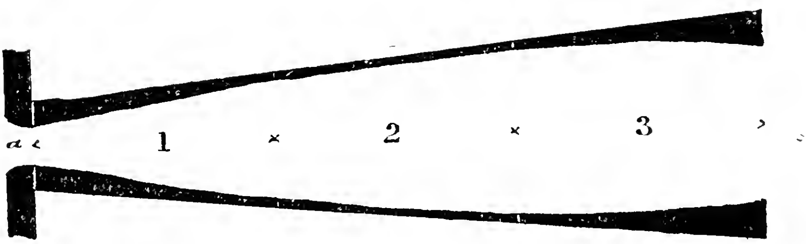


FIG. 2.

Remarks.—This figure gives a section through the axis of the ajutage used in this experiment. It is composed of 3 joints of equal length, which may be screwed together and attached to the mouthpiece (a). The mouthpiece is the same as used in Ex. 1. Joint 1 was used alone with mouthpiece, when set 1 of obs. were taken; joints 1 and 2, when set 2 was taken, and all three, when set three was taken. The ajutage is drawn to scale one-half.

The values of quantities entering the formula for this experiment are as follows :

$t' - t$ = values shown in means for the different sets of obs. $h = 10.00775$; $h_1 = 8.01575$; $h' = 0.84055$; $h_1' = 1.81125$; $A = 8.98274$; $B = 18.43556$; $a = 0.0070882$; $g = 98.0213$.

EXPERIMENT NO. 4.

	No. obs.	$t'-t$ m.	s.	Manometer r'dg at time t dec.	Manometer r'dg at time t' dec.
1	1	0	43¼	0.770	0.510
	2	0	42¾	0.765	0.520
	3	0	42¾	0.760	0.520
	4	0	43¼	0.770	0.540
	5	0	43¼	0.765	0.515
	6	0	43	0.765	0.510
	Means		43.04	0.766	0.519
2	1	0	37	1.37	0.87
	2	0	36½	1.53	0.83
	3	0	35¾	1.40	0.92
	4	0	36¾	1.42	0.82
	5	0	36¾	1.43	0.97
	6	0	37½	1.37	0.92
	Means		36.71	1.42	0.888
3	1	0	35¾	1.65	0.97
	2	0	34¾	1.62	1.09
	3	0	34½	1.55	1.07
	4	0	35	1.55	1.10
	5	0	35	1.62	1.02
	6	0	35¼	1.62	1.12
	Means		35.04	1.602	1.06

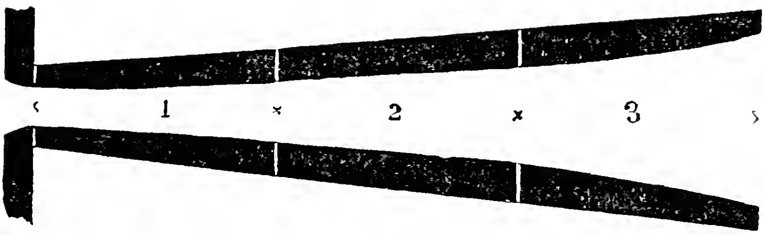


FIG. 3.

Remarks.—The figure shows section of ajutage used in this experiment. It was used in the same way as the ajutage in Ex. 3.

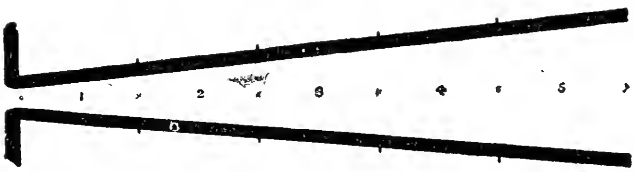
The values of quantities entering the formula are the same as in Ex. 3, except the $(t' - t)$'s, which are shown for the different sets in the means.

EXPERIMENT NO. 5.

	No. obs.	$t'-t$ m.	s.	Manometer at time t. dec.	Manometer at time t'. dec.
1	1	0	35	1.94	1.36
	2	0	34¾	1.91	1.31
	3	0	35	1.89	1.31
	4	0	34¾	1.84	1.36
	5	0	34½	1.94	1.36
	6	0	35	1.92	1.36
	Means		34.83	1.91	1.34
2	1	0	31½	2.51	1.65
	2	0	32¼	2.51	1.65
	3	0	32¾	2.54	1.65
	4	0	32¼	2.41	1.60
	5	0	32¾	2.46	1.55
	6	0	32	2.54	1.75
	Means		32.25	2.495	1 64

EXPERIMENT NO. 5. (*Continued.*)

3	1	0 32	2.70	1.91
	2	0 31½	2.72	1.91
	3	0 31¼	2.65	1.86
	4	0 31½	2.57	1.89
	5	0 31	2.62	1.86
	6	0 32	2.47	1.81
	Means	31.54	2.62	1.87
4	1	0 31¾	2.82	1.90
	2	0 32	2.97	1.90
	3	0 31¼	2.92	1.83
	4	0 30¾	2.83	1.92
	5	0 31½	2.77	1.95
	6	0 30¾	3.00	1.87
	Means	31.33	2.885	1.895
5	1	0 31½	2.85	1.85
	2	0 31½	2.60	1.80
	3	0 31	2.87	1.97
	4	0 31½	2.80	1.80
	5	0 31¼	2.75	2.07
	6	0 30¾	2.95	2.06
	Means	31.25	2.803	1.925



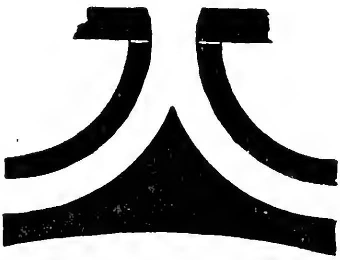
Remarks.—This figure shows a section of the ajutage used in Ex. 5. Scale ¼ Joint 1 used when set 1 was taken, joints 1 and 2 when set 2 was taken, etc.

The value of quantities entering the formula are same as in Ex. 3, except $(t'-t)$'s.

EXPERIMENT NO. 6.

No. obs.	$t' - t$. m. s.	Manometer r'dg at time t. dec.	Manometer r'dg at time t'. dec.
1	0 48	0.72	0.53
2	0 47¾	0.68	0.50
3	0 49	0.70	0.46
4	0 47¾	0.69	0.49
5	0 47¾	0.70	0.49
6	0 49	0.70	0.47
Means	48.21	0.698	0.49

Remarks.—The figure shows an approximate section of the ajutage used in this experiment. The value of a in this experiment is different from the value in pre-



vious experiments, viz., $a = .00695194$. The other quantities entering the formula are the same as in previous experiments, except $t' - t$.

From the above data, computing by (eq. 4) for first experiment, and (eq. 5) for the other experiments, we get the following co-efficients :

First experiment, $C_d = 0.952$

Second experiment, $C_d = 0.945$

Third experiment, $\begin{cases} \text{Set 1, } C_d = 1.693 \\ \text{" 2, "} = 1.790 \\ \text{" 3, "} = 1.786 \end{cases}$

Fourth experiment, $\begin{cases} \text{Set 1, } C_d = 1.518 \\ \text{" 2, "} = 1.780 \\ \text{" 3, "} = 1.865 \end{cases}$

Fifth experiment, $\begin{cases} \text{Set 1, } C_d = 1.876 \\ \text{" 2, "} = 2.026 \\ \text{" 3, "} = 2.072 \\ \text{" 4, "} = 2.086 \\ \text{" 5, "} = 2.091 \end{cases}$

Sixth experiment, $C_d = 1.382$

Having determined the co-efficients of discharge for the mouthpiece and for the ajutages, and having manometer readings at beginning and end of each observation, we can determine whether the increased discharge is accounted for by the measured decreased pressure on the inner walls of the ajutage. We do this by computing the discharge for one second of time through the simple mouthpieee, submerged, assuming the head to be constant and equal to the actual head at time of manometer reading plus the "added head" (found by reducing the manometer reading to a water equivalent), and comparing the result with the computed discharge through the ajutage for one second of time, assuming the head to be constant and equal to the actual head at time of manometer reading.

For the first case the discharge per second for beginning of observation

$$= D_1 = C_d\, a \sqrt{2\, g\, (h - h' + \text{manometer reading reduced to water equivalent}}$$

and for end of obs. =

$$d_1 = C_d\, a \sqrt{2\, g\, (h_1 - h'_1 + \text{manometer reading redučed to water equivalent.}}$$

C_d in this case = 0.945.

For the second case we have the discharge per second for beginning of observation =

$$D = C_d\, a \sqrt{2\, g\, (h - h')}$$

and for end of obs. =

$$d = C_d\, a \sqrt{2\, g\, (h_1 - h'_1)}.$$

C_d in this case being the co-efficient corresponding to the ajutage used.

If the increased discharge is accounted for entirely by the measured decreased pressure on the inner walls of the ajutage we would have very nearly $D = D_1$ and $d = d_1$. I say very nearly because we would expect that the friction in the tubes connecting with the manometer would generally be greater than in the ajutage (the tubes being several feet in length) and hence make D_1 and d_1 slightly less than D and d respective-

ly. The tables below giving the values of D_1, D, d_1 and d show that this is usually the case.

THIRD EXPERIMENT.

Set 1	D	= 0.509 cu. dec.
	D_1	= 0.504 "
	d	= 0.419 "
	d_1	= 0.414 "
Set 2	D	= 0.538 "
	D_1	= 0.537 "
	d	= 0.443 "
	d_1	= 0.438 "
Set 3	D	= 0.537 "
	D_1	= 0.552 "
	d	= 0.442 "
	d_1	= 0.448 "

FOURTH EXPERIMENT.

Set 1	D	− 0.456 cu. dec.
	D_1	= 0.415 "
	d	= 0.375 "
	d_1	= 0.342 "
Set 2	D	= 0.535 "
	D_1	= 0.500 "
	d	= 0.440 "
	d_1	= 0.401 "
Set 3	D	= 0.560 "
	D_1	= 0.522 "
	d	= 0.461 "
	d_1	= 0.426 "

FIFTH EXPERIMENT.

Set 1	D	= 0.564 cu. dec.
	D_1	= 0.556 "
	d	= 0.464 "
	d_1	= 0 464 "
Set 2	D	= 0.609 "
	D_1	= 0.616 "
	d	= 0.501 "
	d_1	= 0.501 "
Set 3	D	= 0.623 "
	D_1	= 0.626 "
	d	= 0.512 "
	d_1	= 0.527 "
Set 4	D	= 0.627 "
	D_1	= 0.652 "
	d	= 0.516 "
	d_1	= 0.530 "
Set 5	D	= 0.628 "
	D_1	= 0.645 "
	d	= 0.517 "
	d_1	= 0.534 "

SIXTH EXPERIMENT.

D = 0.407.
D_1 = 0.397.
d = 0.335.
d_1 = 0.330.

Referring to our table of co-efficients we notice that the simple mouth piece has a slightly smaller co-efficient when submerged than when not. This may be due either to a change of the co-efficient of velocity or of contraction. The ajutage used in third experiment has a much larger co-efficient. By comparing the co-efficients of set 1 and set 2 we see that the length for maximum discharge was passed, it probably being between the lengths used in these sets. The diameter of the outer end of section 3 of this ajutage is smaller than at a point between its ends, and hence a back pressure obtains which tends to reduce the co-efficient.

The ajutage used in fourth experiment has smaller co efficients for Sections 1 and 2 and larger for Section 3 than the above. The length which would give a maximum discharge was evidently not reached. The conical ajutage used in fifth experiment has much larger co-efficients than the previous ones. It is probable that the length which would give a maximum discharge was not reached; it is also probable that the co-efficient found for Sections 3, 4 and 5 of this ajutage are slightly smaller than the true values, owing to counter currents from the side of the receiving tank. An element of the conical surface of this ajutage makes an angle of about 5° 25′ with the axis and the greatest length used in the experiment, about 27 times the diameter of the orifice.

The ajutage used in the sixth experiment does not have as large a co-efficient as was expected to be found, due apparently to counter currents in the ajutage, caused partly by the impact of the jet against the front surface and partly by the impact against the three separators used for connecting the two parts of the ajutage.

The greatest co-efficient found (that for the conical ajutage of five sections) is 2.2 times as great as for the simple mouthpiece submerged and 3.4 times as great as for an orifice in a thin plate. By arranging an over-

flow receiving tank that will just keep this ajutage and mouthpiece submerged, we can take nearly 3.4 times as much water in a given time from a tank than by using a simple orifice of same area—providing the head is large in comparison with the diameter of the ajutage, and is somewhat less than the equivalent of one atmosphere.

Comparing the values of D with D_1 and of d with d_1, we see that in the majority of cases $D > D_1$ and $d > d_1$, as was anticipated; but in third experiment, set 3, $D_1 > D$ and $d_1 > d$, and in fifth experiment, set 2, $D_1 > D$ and sets 3, 4 and 5 $D_1 > D$ and $d_1 > d$. In third experiment this is probably due to the back pressure caused by decrease in diameter of ajutage at the outer end, and in fifth experiment the countercurrents above spoken of may have been the cause by giving the equivalent of a greater friction in the ajutage than in the manometer and rubber tubes.

The results show that the manometer recorded quite closely the difference of pressure on the outer and inner walls of the ajutages, and that this difference fully accounts for the increased flow.

SIZE OF A FIELD PARTY.

By A. M. Van Auken, Member of the Western Society of Engineers.
[Read September 6, 1887.]

About a year ago Mr. A. W. Wright read a brief paper on the size of a field party for location, which I had hoped to see discussed. It is a subject with which I am not very familiar, my whole experience as locating engineer consisting in the running of a single line in the timbered country of Northern Wisconsin. It was a preliminary run with a compass, and the party was as follows:

Chief of party, who was also explorer; transitman, two chainmen, and three axemen; levelman, who also took topography, and rodman; cook.

The provisions were all packed in on men's backs, and any possible reduction in number of the party was desirable, as saving cost of getting in provisions. After settled cold weather of winter set in we left our tents behind to save on moving day. When a man is not in danger of getting wet he will not suffer in open air. Making profile was somewhat troublesome, but we got it done, and the absence of camp stoves and tents on moving day was a relief.

Three men were all we could work to advantage in chopping, an increase led to a wider line of clearing with no gain in progress. The chainmen and rodman changed off with disabled choppers. Hind chainman made, marked and carried stakes. Head chainman was also head flagman, kept choppers in line and selected points. Rodman made and marked all benches, kept a "peg-book" with readings on all turning points, and did the necessary extra clearing for levels. As the country was reasonably level and the compass party could not average over 1½ miles per day, it gave the levelman time to take topography, and with assistance of the rodman pace in all section corners. Pacing is abund-

antly accurate for a preliminary line, and a careful man with practice can pace mile after mile without varying over fifty feet in any case. I have paced three consecutive miles over fairly rough country, finding two section corners burned and coming out within thirty feet of the tree at the third.

Three men constituted the pack train. The moving of camp was done by the party, and every man, chief of party, compassman, levelman and cook included, took a load the first trip, and as many as were needed went back for a second load.

It is the opinion of the writer that altogether too much attention is usually paid on preliminaries to precise instrumental work. He recalls an instance in Eastern Nebraska, where a most wretched line in an easy country was run by a full party in charge of a man who had recently been on river work for the United States Army; instrument men were both recent graduates. Preliminary was run from A. to G., and after a short wait the party started at G. and located back to A. I was told that on arrival at A. the alignment checked to 0° 06′ and the levels to 0.07 feet. This entire party were faithful and believed they were doing good work; yet how much better for the company building had the line been well laid on the ground and the notes of the two lines widely at variance?

As to instruments and tools: I would take on such work a compass, with open sights, and a good needle, the larger the circle the closer can needle be read. For a level I should choose a light one, and a self-reading rod. On the line mentioned the rod was pine, twelve feet long, with feet and tenths marked in black on white ground. The Chicago, Milwaukee & St. Paul at one time furnished a rod about 1¼ inches square, marked as above, but made of maple and supplied with a target with vernier reading to hundredths. It was very convenient.

I would choose a chain with brazed links, soft enough not to break easily on a cold morning, and heavy and hard enough so as not to give too much trouble from bending. Always carry a roll of copper wire with you for mending chains, tripod legs, etc.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

SEPTEMBER 21, 1887 :—A regular meeting of the Boston Society of Civil Engineers was held at Room 27, Boston & Albany Station, Boston. The meeting was called to order at 7:45 P. M. Twenty-seven Members and two visitors present.

In the absence of both the President and the Vice-President, Mr. FitzGerald was elected President *pro tem*.

The record of the last meeting was read and approved.

Vice-President Stearns then assumed the chair. Messrs. Lucian A. Taylor and Erastus Worthington, Jr., were elected Members of the Society.

The following were proposed for membership : Mr. Phinehas Ball of Worcester, recommended by A. F. Noyes and E. L. Brown ; and Mr. Lyman L. Gerry of Stoneham, recommended by A. F. Noyes and A. S. Glover.

Prof. Chaplin presented the address of the Board of Managers, asking for the appointment of delegates to a convention of engineering societies (see May, 1887, number of JOURNAL), and moved that the President be authorized to appoint delegates to attend the convention whenever it should be called by the Board of Managers.

After an explanation by Prof. Chaplin of the object desired by the Board of Managers, and a discussion in which Messrs. Allen, Brooks, Chaplin, FitzGerald, Folsom, Howe and Stearns took part, the motion was withdrawn. Then, on motion of Prof. Chaplin, the address was referred to the Government, to report at the next meeting.

Mr. Frank W. Hodgdon read a paper entitled "Methods Used in Filling a Portion of South Boston Flats."

Mr. C. W. Folsom exhibited a plan showing the location of a washout which occurred on the Boston & Lowell Railroad, near Arlington, Mass.

[*Adjourned.*] S. E. TINKHAM, Secretary.

WESTERN SOCIETY OF ENGINEERS.

SEPTEMBER 6, 1887 :—The 239th meeting was held at 8 P. M., President Artingstall in the chair.

The minutes of the preceding meeting were read and approved.

Mr. Moritz Lassig, bridge builder, 534 Garfield avenue, Chicago, and Mr. George H. Brenner, Assistant Engineer, West Iowa Division C., B. & Q. R. R. Red Oak, Iowa, were proposed as Members.

Mr. William A. Lydon, Assistant Engineer Drainage and Water Supply Commission, City Hall, Chicago, was elected a Member.

Two papers were read and discussed: The Municipal Engineer and the Management of his Office, by Mr. Schreiner ; and Size of a Field Party, by Mr. Van Auken.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

MAY 10, 1887 :—Regular meeting held, President Whitelaw in the chair. The minutes of the last meeting were read and approved.

On motion, the President was authorized to appoint a committee to arrange for a fitting testimonial to past President J. F. Halloway, before his departure from the city.

On motion, the Chair was authorized to appoint a committee of three to report upon the advisability of amending the constitution and by-laws of the Club.

The Committee on Membership submitted a list of Members who are one, two or three years in arrears for annual dues, and asked that action be taken thereon by the Club. A resolution was adopted directing that all Members who are more than two years in arrears be stricken from the rolls.

Mr. George E. Hartnell was elected an active Member of the Club.

Mr. C. P. Leland read a paper entitled "A History of the Lake Shore & Michigan Southern Railway."

On motion, the Committee on Library and Publication was instructed to prepare and publish the Club calendar containing a list of Members in form for pocket use.

The Chair appointed Messrs. W. H. Searles, M. E. Rawson, and A. Mordecai as the Committee on Revision of Constitution and By-Laws, and Messrs. E. H. Jones, M. W. Kingsley, C. P. Leland, John Eisenmann, H. M. Claflin, and W. P. Rice a Committee on Testimonial.

[*Adjourned.*] CLARENCE M. BARBER,
Recording Secretary.

JUNE 14, 1887 :—Regular meeting held, President Whitelaw in the chair. The minutes of the last meeting were read and approved.

The Committee of Revision of the Constitution and By-Laws, through it chairman, W. H. Searles, reported, recommending that a committee of seven be appointed to revise the consti ution and by-laws of the Club; report adopted, and the following persons were appointed as such committee: W. H. Searles, A. Mordecai, John Eisenmann, M. E. Rawson, W. P. Rice, Ambrose Swasey, and C. M. Barber. The Secretary reported the receipt of the following publications: "Trautwine's Civil Engineer's Pocket-Book." from J. C. Trautwine, Jr.: "Proceedings of the Southern Society of Civil Engineers," "Flyers," from the Engineers' Society of Western Pennsylvania: "The Annual Report of the Philadelphia Natural Gas Company," by Charles Paine, and selected papers from the Rensselaer Society.

Mr. C. F. Schultz was elected an active Member of the Club. Mr. J. N. Stockwell read a paper entitled, "The Use of the Horizontal Telescope for Determining Differences of Latitude and Longitude." A discussion followed.

[*Adjourned.*] CLARENCE M. BARBER,

Recording Secretary.

JULY 12, 1887 :—Regular meeting held, President Whitelaw in the chair. Minutes of the last meeting were read and approved.

Mr. E. H. Jones, Chairman of the Committee on Testimonial Banquet to Mr. Holloway, reported a balance of money left on hand after the banquet, and made a motion that a committee be appointed to prepare and present proper resolutions of respect for Mr. Holloway, and that the balance of money on hand be used to pay for engrossing such resolutions. Motion carried.

The President called attention to the portrait of Mr. Holloway which had been presented to the Club.

Mr. Charles Latimer read a paper entitled "Civil Engineering and Surveying," which was followed by discussion.

The Secretary announced the following publications as having been received : "Wellington's Railway Location," from the author ; "The International Standard," "Transactions of the American Society of Civil Engineers." Hoyers from the Western Society of Western Pennsylvania.

A letter was received containing the resignation of Wm. M. Wood.

The President announced the Committee on Resolutions of Respect to Mr. Halloway as follows : Chas. Latimer, E. H. Jones, W. H. Searles, John Walker and H. M. Claflin.

[*Adjourned.*] CLARENCE M. BARBER.
Recording Secretary.

AUGUST 9 :—Regular meeting held, President Whitelaw in the chair. In the absence of the Recording Secretary, Mr. J. Ritchie was appointed Secretary *pro tem.* The minutes of the last meeting were read and approved.

Mr. G. R. Hardy, Assistant Chief Engineer of the L. S. & M. S. R. R. was elected an active Member of the Club.

Upon the recommendation of the Committee on Membership, the resignation of Mr. W. M. Wood was accepted.

Mr. J. H. Sargent read a paper entitled "A History of Railroads between Cleveland and Chicago."

Mr. H. C. Thompson read a paper on "A Method of Building a Second Track for Single Track Railroads." After discussion, the President stated that two volumes of a French publication on Hydraulic Machinery had been received by the Club from some unknown source.

[*Adjourned.*] JAMES RITCHIE,
Rec. Sec. *pro tem.*

SEPT. 13, 1887 :—Regular meeting held. President Whitelaw in the chair. The minutes of the last meeting were read and approved.

Mr. John Walker gave a brief description, with illustrations, of a "New Method of Heating and Ventilating Workshops," as adopted at the Walker Manufacturing Company's works in this city. The method and advantages were discussed by the Members. By request of Mr. Walker, Mr. Julius Roemmele explained his method of using his patent key-way gauges, and requested the opinion of the Members as to its advantages, etc. After discussion of the subject, the Club adjourned.

JAMES RITCHIE, Rec. Sec'y *pro tem.*

ENGINEERS' CLUB OF MINNESOTA.

SEPTEMBER 9, 1887:—A regular meeting was held at the City Hall, 7:30 P. M, Present, President Sublette, Messrs. C. D. Redfield, Wm. R. Hoag, John Barr. F. C. Deterby, G. S. Houston, Fred Kees, and W. S. Pardee. Visitors, Messrs. S. Starkey, and Wilson, of St. Paul Club.

The minutes of the last meeting were read and approved.

Mr. G. S. Houston reported for the committee on making excursion arrangements with the St. Paul C. E. Club, that he had conferred with the committee of the latter Club, and conditional terms had been made with the railroads.

On motion, the Club appointed the 25th inst. as the day for an excursion to the city of St. Louis via Chicago. Time to be taken in each city, and at other desirable places to investigate engineering and other instructive works.

The Committee on Arrangement were instructed to attend to all details of the excursion.

On motion of Mr. Houston an invitation to attend the Minneapolis Exposition

was extended to the St. Paul Civil Engineers' Club. Time, Thursday, the 15th inst., at 8 P. M. The invitations were ordered printed and mailed to the Secretary of the St. Paul Club.

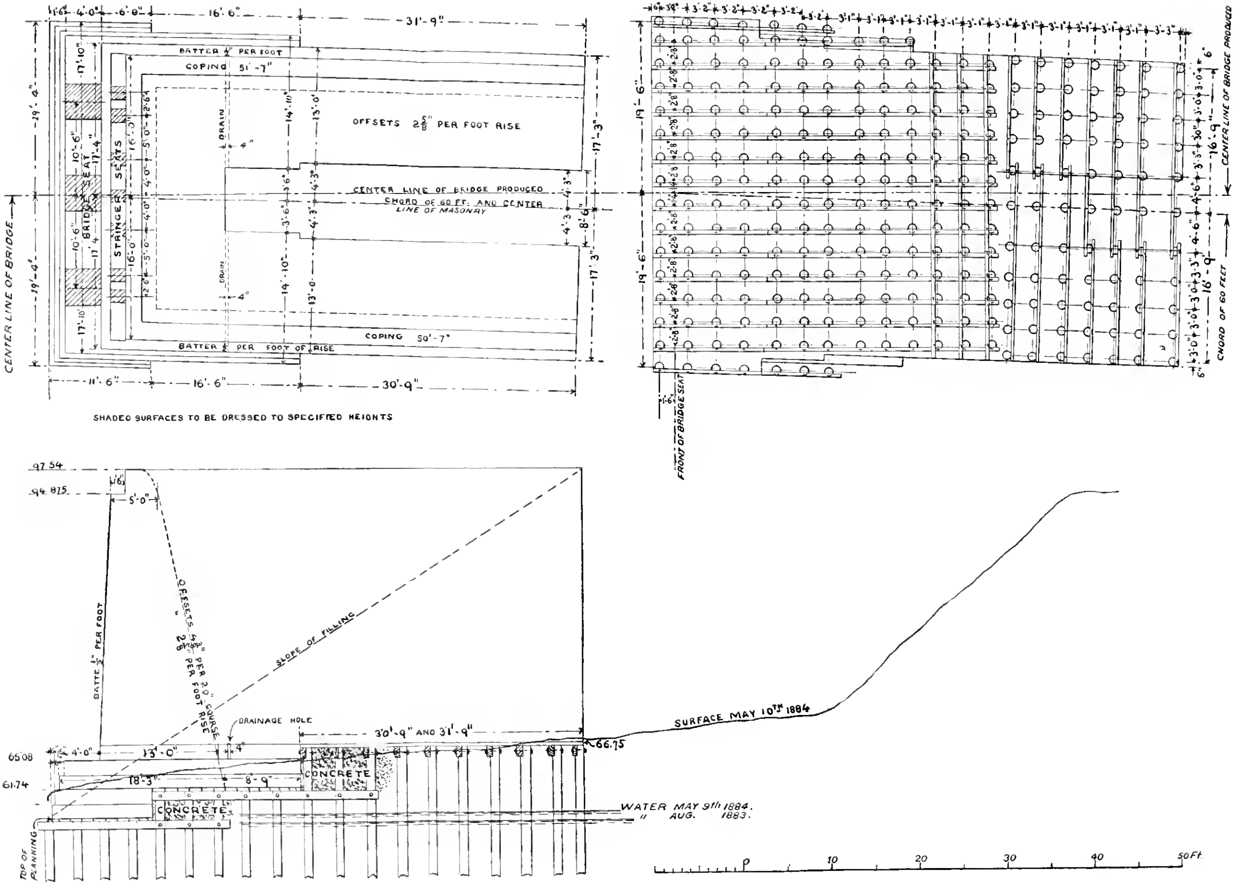
Mr. Fred. G. Corsar was elected to membership in the Club, and the names of A. H. Lenton, George M. Goodwin, Horace H. Horton, George E. King were proposed for membership, certified to by G. N. Sublette and G. S. Houston.

Messrs. Redfield and Kees were appointed a committee to escort the visiting members of the St. Paul Club about the city.

The literary exercises were begun by the reading of Mr. J. Riggs' discussion on President Sublette's paper, "Railroad Legislation." The Club then took part in a general discussion of the paper.

Mr. J. Rigby gave notice that he would read a paper on Light and Gas at the next regular meeting.

[*Adjourned.*] WALTER S. PARDEE, Secretary.



PLAN OF THE NORTH ABUTMENT FOR A BRIDGE OVER THE COCHECO RIVER, BOSTON & MAINE RAILROAD

EDWARD S. PHILBRICK, *Engineer*, 1884.

ASSOCIATION OF ENGINEERING SOCIETIES.
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THE LAND-SLIDE OF MAY 1, 1884, ON THE BOSTON & MAINE RAILROAD, NEAR DOVER STATION.

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The line of the Boston & Maine Railroad crosses the Cocheco River a few hundred feet west of Dover station and a short distance above the dam of the Cocheco Manufacturing Company. The stream, or rather mill-pond, is about 140 feet wide at the point of crossing. The bottom is composed of a soft mud, resting on a soft clay, with a sub-stratum of stony gravel at a depth of 35 feet below low water on the west bank to 42 feet on the east bank. The extreme range of the water level in the pond during the year 1883 was six feet. The greatest depth of water was near the east shore, about 20 feet.

The western or right bank of the river was a meadow several hundred feet in width, and but slightly elevated above high water. Over this meadow the railroad had been constructed many years before, by an embankment about 30 feet high. The left or eastern bank rose in a steep natural bluff from near the water's edge to the grade of the railroad. It was covered with grass and bushes, with scattered trees. At the top of this bluff was a table land, on which the city of Dover is located, about 34 feet above high water in the river. Just south of the railroad location, near the edge of the bluff, stood a large ice-house. The table-land at the bluff is composed of alluvial sand for a depth of some 10 feet below the surface, resting on a stratum of blue clay, mixed with just enough very fine sand to allow water to soak into it slowly, with horizontal veins of pure sand at intervals, carrying water freely to their outcrop on the face of the bluff, where the water appeared in springs.

The railroad had formerly crossed the stream on a wooden truss deck bridge of two spans. The pier in the river had been built on a wooden

crib, resting on a platform of timber. It was composed of only a few courses of stone above the crib, less than 10 feet high. The eastern abutment had been located on the face of the slope, perhaps 10 feet above high water, on a timber platform in the clay. This structure had been giving trouble by slipping forward on its clay bed.

The old bridge was worn out and weak. Plans had been matured in 1883 for rebuilding it for a double track with a single span of about 150 feet, placing the abutments in front of the old ones and dispensing with the pier. During the winter of 1883–4 a temporary trestle was built around the old bridge, so the work could be prosecuted without the incumbrance of the traffic. The new work was put under contract, the foundations and masonry to one party and the iron superstructure to another. Early in the spring of 1884 the foundation piles had been all driven for both abutments, and workmen were beginning to cut off the pile-heads to apply concrete between them. As a preliminary step to this operation a light coffer dam was constructed all around the foundation of the east abutment by driving sheet piling into the clay, bracing across the pit as the digging progressed. The abutments were planned with wings nearly on the same plane as the face, stepping down to conform to the slope of the embankment, commonly known as "spread eagle" wings. The piling had been driven from 45 to 50 feet into the clay and gravel. Borings had been made by driving gas pipe and forcing out the material from within them with a water jet. These borings showed soft clay in strata from 6 feet to 16 feet in depth, separated by veins or strata of sand from 1 foot to 4 feet in thickness. A hard gravel or rock was met 54 feet deep, with 2 or 3 feet of stony gravel on it. When digging between the pile-heads the last day of April, 1884, the old clay slope above showed repeated signs of instability, cracking off and sliding down against the coffer dam, which was being strongly braced across the pit as the digging progressed. The excavation for 10 feet in length at the north end of the northern wing was about done and some of the piles had been cut off, when cracks began to open in the soil on the top of the bluff about 30 feet back from the top of the slope on the afternoon of April 30. At noon of May 1, a freight train passed over the trestle, immediately after which the whole mass outside the crack began to sink, slowly, steadily and perpendicularly, till it had settled some 30 feet. One man who was standing near the edge of the bluff went down without losing his balance, holding a lot of books under his arm. There were five men below, who had just dropped their tools and were preparing to go to dinner. Hearing shouts from above four of them ran across the moving mass and escaped unhurt, though the soil was gliding under them " like the platform of a treadmill." The fifth man was in charge of a hoisting engine. Both he and the engine were carried to the middle of the river, both disappearing under the water. The engine was thrown to the surface about half way across and the man soon extricated himself near the west bank and swam ashore. How he escaped the falling derrick guys and pile drivers is a mystery that he was unable to explain. The flow did not move directly towards the river, but obliquely up stream. Its direct path was obstructed by the piling of the abutment foundation, which extended along the shore for 125 feet in length. The

moving mass seems to have included the clay for a depth of some 20 feet below the top of the abutment foundations, or pile-heads, for the piles in the northern wing of the abutment were broken off in the ground about that length below their tops and swept along with the flowing clay into the middle of the river channel, where they stood bristling at all possible angles. The mass in motion probably contained some 8,000 cubic yards, weighing over 120 pounds per cubic foot, or about 18,000 tons. The flow continued till checked by the opposite river bank, completely damming the water for the time. An elm tree which had stood on the slope, about 40 feet high, stood upright in the middle of the river for some months afterwards, continuing to grow, on an island, after the river had risen and washed a new channel on each side of it through the soft clay. The writer first saw the ground on the 4th of May, three days after the slide. The face of the bluff was then nearly perpendicular from the top down about 15 feet, with a steep talus below for 10 feet more, and thence a gentle slope to the middle of the river. Much of the sand which had lain on the top of the clay lay there still, as if the clay had flowed out from under it. Where the clay was exposed it was so soft that a pole could be pushed down 10 feet or more by the strength of one hand. When handled it was about the consistency of putty as used by glaziers, though a few days' exposure to the air caused the surface to stiffen and crack. A portion of the slide had carried away some 20 feet of the trestle over which the railroad traffic was passing. While reconstructing this, the top of the bank cracked again some 6 to 10 feet back from the edge and slid off, again breaking the trestle. The edge of the bluff had now cracked away to within such a short distance from the ice-house on the south side that it was feared the weight of the ice might precipitate further slides, and interrupt the passage of trains indefinitely. But this fear was not realized. The later cracks, and the shovels of a gang of men put on for that purpose, soon rendered the face of the slope less precipitous and more stable.

It is worthy of notice that this bluff had remained in an apparently stable condition for centuries, except the slight tendency of the old abutments to slip forward. There had probably never been a large margin in favor of stability, however, and several new conditions combined to destroy the equilibrium when the slide took place. The natural conditions heretofore existing through an indefinite period were as follows: A mass of alluvial sand some 10 feet thick, resting on a bed of soft clay over 50 feet deep, intersected with nearly horizontal water-bearing veins of sand at intervals of 3 feet to 16 feet. The river had, at some remote date, eroded about half the depth of the clay, leaving the bluff as steep as its materials would stand. Copious rains, during the previous months, had saturated the table land, and the sand veins were carrying a good deal of water, while the clay itself was so far mixed with fine sand as to allow water to permeate its whole mass and soften it.

The coffer dam along the edge of the river, 125 feet in length, obstructed the drainage of water from these sand veins where they cropped out against the river channel under water, and thereby aggravated the saturation of the mass of clay. The constant traffic on the railroad trestle close by kept the whole neighboring earth quivering, and tended to

destroy the friction between its parts. The final touch which served to pull the trigger and launch the heavy mass, was the digging of the foundation pit at the foot of the slope. This served as a warning to discourage further attempts to excavate in a material which, while about twice the specific gravity of water, was essentially governed by the laws of fluid pressure and fluid motion to a large degree, and too little elevated above the river to admit of drainage to any appreciable depth below its surface.

Several schemes were suggested for rebuilding the bridge, such as to lengthen the span and set the east abutment back from the river, or make an additional span over the ground from which the clay had flowed, putting a pier where the east abutment had been begun.

But as no additional length of bridge beyond what had already been planned was really needed for water-way, and as the clay was apparently as soft 75 feet back from the river as anywhere, there did not seem to be any good reason for a greater length of bridge. Moreover, the iron superstructure was completed and ready for erection. It was, therefore, determined to build a new abutment on the site of the one already begun and use the iron work of the bridge without change.

The first step was to drain the surplus water out of the material between the river bank and the face of the bluff where the slide had taken place. For this end a trench was dug some three or four feet deep, extending all around the site of the proposed new abutment and discharging into the river near the actual water-level at both ends.

A plank box with holes in the bottom was buried in this trench, and the surface on which work was to be done soon became more stable.

The "spread eagle" plan for the abutment was abandoned, and a plan adopted with wings parallel to the tracks, long enough to enable a stable slope of earth ($1\frac{3}{4}$ to 1) to fold around outside of each wing, starting at the grade of the roadbed at the end of the wings, and reaching the natural surface at the face just below the bridge seat, the bridge being a deck bridge, with the lower chords only a few feet above high water. Thus the foundation was a parallelogram 62 feet long, parallel with the tracks, and 40 feet wide at right angles to them. This space was set full of piles about 3 feet on centres each way, and the piles capped by 6 x 12 inches hard pine timber, set edgewise, the pile heads being cut half off with a shoulder to receive them. The timber was bolted to every pile by a 7-8 inch bolt and nut. For 40 feet back from the face the timbers ran parallel to the track and transversely for the rest of the length of the wings. The whole space between the wings was treated in the same way, and a platform of 3-inch spruce plank was spiked down, tying the piles together in a direction tranverse to the timbers.

The clay was about 8 feet higher at the end of the wings than at the face of the abutment. The platform near the river bank was to be just below the summer stage of the river. If the whole were made level, the end of the foundation furthest from the river would require some 10 feet of excavation. It was not thought prudent to dig such a pit for fear of disturbing the equilibrium then existing in the semi-fluid mass. But as the clay was of such a character as to never lose its water by evaporation or drainage a few feet below the surface of the future grading, the platform

was made in steps, the foundation at the ends of the wings for 30 feet in length being 8 feet above the platform at the face next the river. There were two steps, as shown in the drawings, with timber lapping past them to secure continuous ties.

The piling was begun the latter part of May, as soon as the timber could be obtained, and the whole work completed ready for the traffic in November.

As the planking of the platform over the space between the wings might have been unable to support a load of gravel 30 feet high, this space was filled with locomotive cinders, a material having only half the weight of gravel.

During the driving of the piles it was found that when half or two-thirds down, they would float out of the clay slowly if left unloaded. They could not be so left until their lower ends were driven some feet into the stony gravel below the clay. A row of leaning piles was driven along the face next the river, their heads being bolted back to the others, and a large quantity of broken stone was dumped in the mud in front as a buttress. The bridge has been closely watched since its completion. The western abutment standing on a better quality of material (gravel and sand), was completed as first planned, with the straight wings, and has kept its form.

The eastern abutment began to move perceptibly within a year after its completion. A careful survey shows that each abutment has now moved forward bodily, as a monolith, about 4 inches, bringing the western or rolling end of the bridge against the abutment wall. There is about 6 inches more space at the east end, but in order to use it to relieve the bridge from possible crowding, the eastern end must be cut loose from the masonry and the whole structure moved endwise, so that the spare room may be at the rolling end.

No crack has appeared in any part of the masonry. Its pointing is still perfect. It has moved forward as a single block. Its weight is about 3,000 tons for each abutment. Its future movements will be of interest to the profession. It is the opinion of the writer that no other plan of foundation could produce a result equally stable, short of a pneumatic caisson foundation sunk to the hard bottom some 40 feet under water. Such a plan would have involved a large cost, and the delay would have rendered it difficult to maintain the trestle for railroad traffic during the winter months, when a heavy coat of ice would have formed in the pond, crowding the trestle and lifting it with a prodigious force whenever the river should rise.

The peculiar feature of the foundation is the construction of the timber platform with steps as we recede from the river. Such a construction would in most cases expose the timber to decay, but this clay had remained so saturated with water through the dry seasons for over twenty years that the timber platform under the old abutment had not suffered from decay, though higher than any part of the new one, and more exposed to evaporation, the new one having greater depth of filling over it than the old.

ON THE USE OF THE HORIZONTAL TELESCOPE FOR DETERMINING DIFFERENCES OF LATITUDE AND LONGITUDE ON THE EARTH.

By Prof. John N. Stockwell, Member of the Civil Engineers' Club of Cleveland.

[Read June 14, 1887.]

One of the most important problems which have attracted the attention of mankind from the earliest ages is the determination of the figure and dimensions of the earth. Aristotie relates that the mathematicians prior to his time had found the circumference to be 400,000 stadia. It follows, therefore, that the earth, even at that early age, was known, or at least supposed to be, spherical. But the records of the principles and measurements by which the circumference was determined have not been preserved to our time.

If we assume the length of the stadium to be 606.75 feet, or 0.11493 of a mile, a circumference of 400,000 stadia would correspond to a diameter of 14,600 miles; which may be regarded as a first approximation to the earth's diameter.

The measurements mentioned by Aristotle were probably made as early as the year 400 B. C.; and we have no account of other measurements for the same purpose until the time of Eratosthenes, who lived about the middle of the third century B. C., and who has explained the methods and preserved the measurements by which the mathematicians of his time determined the magnitude of the earth. The general principles employed in the solution of the problem in those early ages were essentially the same as are employed at the present time; although the necessary measurements for the purpose were very crudely and imperfectly made. It was known from observation that on the day of the summer solstice, at noon objects cast no shadows at Syene, in Upper Egypt; whence it follows that the sun was at that instant in the zenith, whereas at Alexandria, in Lower Egypt, on the same day the sun's zenith distance at noon was found to be 7° 12′. Supposing, therefore, that these two places were situated in the same terrestrial meridian (which is nearly true), it would follow that they were separated by *one-fiftieth* of the whole circumference of the earth. Now, the distance between the two places was believed to be 5,000 stadia, whence it followed that the whole circumference was 250,000 stadia; and this would correspond to a diameter of more than 9,000 miles, which may be considered as a second approximation to the diameter of the earth. Modern determinations show that the difference of latitude between Alexandria and Syene was very correctly determined; the distance between the two places must, therefore, have been very imperfectly known, provided the length of the stadium was what we have supposed.

The actual great circle distance between Alexandria and Syene is 524 miles, and if we assume this as equal to 5,000 stadia the length of the stadium comes out about 53 feet shorter than the value we have supposed.

The next attempt to determine the magnitude of the earth was made

by Posidonious, about the beginning of the first century B. C. This astronomer determined the difference of latitude between Alexandria and Rhodes by means of the meridian altitude of the bright star Alpha Argus (*Canopus*). At Rhodes this star was barely visible above the horizon, while at Alexandria it rose to the height of a quarter of a sign, or 7° 30′, which is the forty-eighth part of the circumference. He also assumed the distance between the two places to be 5,000 stadia, although the distance had been estimated by Eratosthenes, two centuries earlier, as only 3,750 stadia. Posidonious, therefore, concluded that the circumference of the earth was equal to 240,000 stadia, which corresponds to a diameter of about 8,800 miles.

Posidonious has not informed us in what manner he determined the distance between Rhodes and Alexandria; and as the intervening distance is wholly occupied by the waters of the Mediterranean, it is evident that no direct measurement of the distance was possible. But the actual difference of latitude between Rhodes and Alexandria is only 5° 15′ instead of 7° 30′; and the actual distance between them is only about 3,300 stadia instead of 5,000, so that the two errors nearly balanced each other, and Posidonious obtained nearly the same value for the earth's diameter as had been previously found by Eratosthenes.

But the observations of the meridian altitudes of Canopus at Rhodes and at Alexandria by Posidonious must have been very deficient in accuracy, for the latitude of Rhodes is 36° 25′, and that of Alexandria is 31° 10′, while the declination of the star Canopus 2,000 years ago was 52° 45′ south, differing only 8′ from its declination at the present time. It therefore follows that the true meridian altitudes at Rhodes and Alexandria must have been 0° 50′ and 6° 5′ respectively; and these would have been further increased by refraction, so that their apparent altitudes must have been 1° 13′ and 6° 13′, thus making the apparent difference of latitude only 5° instead of 7° 30′, or just two-thirds of the distance estimated by Posidonious.

Early in the ninth century the Arabians measured an arc of the meridian on the plains of Mesopotamia; but the details of their measurements have not been preserved to our times, and consequently our knowledge of the figure and dimensions of the earth has not been increased by their labors. This closes the historical notice of the really ancient determinations of the earth's magnitude, and we shall now proceed to give an account of the modern determinations of the same element.

The first of the modern attempts to measure the magnitude of the earth was made by Fernel, a French physician, about the middle of the sixteen century. He counted the number of revolutions which his carriage-wheel made in going from Paris to Amiens, which are very nearly in the same meridian, and he determined the length of a degree of the meridian to be 364,960 English feet, which, supposing the earth to be a sphere, would correspond to a diameter of about 7,921 miles. This is a very close approximation, and differs only about *four miles* from the earth's mean diameter, according to the laborious and refined methods of the present day.

The next attempt to determine the length of a degree of the meridian was made by Norwood in the year 1635. By a method somewhat similar

to that employed by Fernel, he measured the distance from London to York; and by noting the bearings and lengths of the different courses, he reduced his measures to a meridian line and also to the sea level, and finally concluded that the length of a degree between London and York was 367,176 feet. This differs from the actual distance by 2,100 feet, and is far less accurate than the measurement by Fernel, which differed by only 133 feet from the truth.

This brings us to the consideration of the refined methods of the present day, and we need only stop to explain their general nature and estimate the precision of which they are capable. The methods at present employed are of two kinds, namely: *First*, by measurements of the length of an arc of the meridian, together with the exact geographical latitudes of its extremities; and *second*, by measuring the length of a parallel of latitude, together with the exact difference of longitude of its extremities. Now, the length of an arc on the earth's surface may be determined with almost any desirable precision, but the determination of the exact geographical latitude of any point of the surface is a matter of very considerable difficulty. We know, however, that an arc of 1″ on the earth's surface is equal to about 100 feet; so that were we able to determine the latitude of a place with a probable error of only 0.01″, the *difference of latitude* of two places thus determined might be in error by double that amount. In other words, if our measured arc subtends an angle of exactly 60″ at the centre of the earth, the difference of the measured latitudes might be 59.98″ or 60.02″, and this small error would produce an error of nearly three miles in the estimated diameter of the earth.

In reality, the probable error of latitude determinations by the instruments generally used for that purpose is nearly twenty times the value we have supposed, so that we could scarcely rely upon the accuracy of a determination of the earth's diameter from so small an arc within a limit of one hundred miles. It is therefore necessary to measure very long arcs of the meridian in order to neutralize the effect of the errors of latitude determinations.

In order to illustrate what has been said in regard to the accuracy of latitude determinations, we shall take an example from the recent records of an observatory. During the years 1876–77, Professor Doolittle made an extended series of observations for the purpose of determining the latitude of the Sayre observatory, at Bethlehem, Pennsylvania. He used the zenith-telescope of the Lehigh University, and observed sixty pairs of stars, making 459 observations in all. Every precaution seems to have been taken to secure an accurate result. The latitude thus obtained was 40° 36′ 23″.905, with a probable error of only 0″.037. In 1885–86, he repeated the observations on fifty-seven of the same pairs of stars, making 288 observations in all. This second series of observations being reduced in the same manner as the first, gave 40° 36′ 23″.512 as the latitude of the observatory, with a probable error of only 0″.051. The difference of these two very elaborate determinations is 0″.393, or about double the quantity which was assumed as a maximum error of a determination of latitude.

Now we cannot properly suppose that the latitude of the observatory

has changed during the nine years between the two sets of observations. In fact, we have no evidence that terrestrial latitudes ever change; but on the other hand we have very good evidence that the latitude of a place is one of the most permanent elements of nature. Thus the latitude of the Naval Observatory at Washington, as determined at intervals of eighteen and twenty years was as follows:

In 1845,	Latitude =	38° 53′ 39.25″
1863,	" =	38.78″
1883,	" =	38.94″

And the latitude of Greenwich Observatory, as determined by observations between

1836–1849	give	Latitude =	51° 28′ 38.15″
1851–1865	"	" =	38.13″
1866–1879	"	" =	38.17″

These determinations are so nearly identical as to preclude the hypothesis of a change of latitude. Moreover, a change of latitude of any place implies a shifting of the pole of the earth; and a shifting of the pole further implies a change in the direction of all terrestrial meridians, except the one along which the pole is traveling. But no such change in the direction of the meridians has been detected by observation, and therefore the hypothesis of a change of latitude is at present untenable. It is therefore necessary to measure very large arcs of the meridian in order to neutralize the effect of errors in the determination of latitudes; but this method of overcoming the defects of latitude determinations is correct only on the supposition that the measured arcs of meridian are themselves free from error, which is not strictly true.

Having explained the difficulties attending the measurements of arcs of the meridian, we shall now consider those incident to the measurement of an arc of parallel. The chief difficulty attending the measurement of an arc of parallel arises from the uncertainties in the determination of the difference of longitude between the two stations. For this reason there have been very few attempts to measure large arcs of parallels; but the most important, extensive and systematic measurement was made some sixty-five years ago, along the parallel of 45° 43′ 12″ from *Marennes* on the west coast of France to *Padua*, near the eastern coast of Italy, a distance of 628 miles. The arc embraced nearly thirteen degrees of longitude, and was divided into six sections, which were independently measured, and every precaution was taken to secure the greatest possible accuracy. The sections varied in length, being measured by the difference of longitude between any two consecutive stations. The following table contains the lengths of the different arcs in feet, and also the values of the corresponding arcs of longitude as estimated by the observers:

Arcs.	Amplitudes. Min.	Sec.	Length in feet.	Length of one minute.
1. Marennes to St. Preuil......	3	48.99	244,123	4264.4
2. St. Preuil to Sauvagnac....	6	23.09	407,429	4254.1
3. Sauvagnac to Isson...... ..	6	51.39	437,493	4253.8
4. Isson to Geneva............	11	57.82	764,736	4261.4
5. Geneva to Milan............	12	9.57	776,646	4258.1
6. Milan to Padua.............	10	45.38	686,549	4255.1
Total length...............	51	56.24	3,316,976	4257.8

The length of the arc of one minute in feet is found by dividing the length of the whole arc by the number of minutes of a degree in its

amplitude. The difference of longitude between any two consecutive stations was determined by fire-signals at intermediate points. The whole arc between *Marennes* and *Padua* gives 4257.8 feet for the arc of one minute of longitude on that parallel; which is 1.2 feet greater than it should be according to Bessel's spheroid, and exceeds the value required by Clarke's spheroid of 1880 by 6 inches. A comparison of the numbers in the preceding table shows that by measuring an arc of two or three degrees we should be tolerably certain of finding the length of an arc of one minute of longitude on that parallel with a probable error of about 4 feet. This shows the very great difficulty attending the accurate measurement of an arc of parallel.

The differences of longitude in the preceding table were determined before the invention of the telegraphic method, and it becomes a matter of considerable interest and importance to know to what extent they are confirmed by the improved methods in use at the present time.

For this purpose we shall observe that the longitudes of the observatories of the three eastern stations, *Geneva*, *Milan* and *Padua*, which were points of the triangulation, have been determined by the telegraphic method, and give

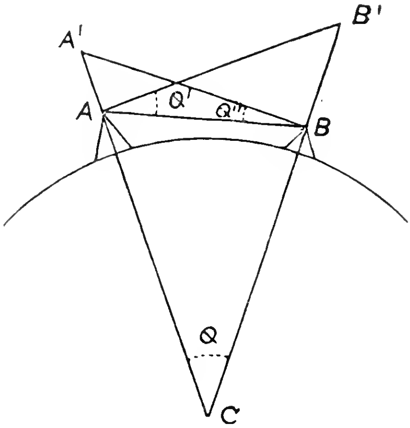
Milan—Geneva	= 12 min.	9.20 sec.
Padua—Milan............................	= 10	43.16

If we assume these numbers to be correct, it follows that the numbers in the table are erroneous by the quantities 0.37 sec. = 5.″55, and 2.22 sec. = 33.″3, respectively. And these corrections would change the lengths of the corresponding arcs of 1 minute of longitude from 4258.1 to 4260.2, and from 4255.1 to 4269.8, the latter being changed by nearly 15 feet, and the accordance of values derived from the whole six arcs being much less perfect than before. The value of the arc of one minute of longitude derived from the corrected value of the whole arc is 4261.3, which is 4.7 feet greater than it should be, according to Bessel's spheroid, and 4 feet greater than is required by Clarke's spheroid.

We thus see that the determination of the absolute latitude of a place, as well as the difference of longitude between two places, is a matter of very great difficulty; and a writer in the *Encyclopedia Britannica* tells us that the latitudes of the best determined spots on the earth are uncertain by *one-half* a second; and also that the differences of latitude can be determined with greater precision than differences of longitude. If we at present admit that the best determined latitudes are uncertain by one-quarter of a second, and that differences of longitude are uncertain within somewhat wider limits, it is the object of this paper to explain how we may obtain these differences of latitude and longitude with less than the *one-hundredth* part of the error which attends their determination astronomically. And for this purpose I have conceived a telescope to be endowed with certain peculiarities which will serve special purposes and distinguish it from other engineering and astronomical instruments, and have designated it by the name of *Horizontal Telescope.*

Since the *zenith telescope* is employed for determining the angular distances of the celestial bodies from the zenith, so in like manner it is the object of the horizontal telescope to determine the angular distance of errestrial objects, situated at a finite distance, from a line truly hori-

zontal at the place of the observer. By measuring such mutual angular distances between any two places on the surface of the earth, which are visible from each other, we have at once the means of determining the angular distance between such places, when viewed from the earth's centre; or rather when viewed from the point where the normals to the earth's surface at the points of observation intersect each other.



For let A and B denote two points of observation, and C the centre of the earth; then if AB' and $A'B$ are two truly horizontal lines at the points A and B, the angle ACB will be equal to $ABA' + BAB'$; that is the angle at the centre of the earth will be equal to the sum of the angular depressions of the points A and B when viewed from each other. For, if we denote the angles ACB, BAB', ABA' by θ, θ', θ'', we shall have $CAB = 90° - \theta'$, $CBA = 90° - \theta''$; their sum will be $180° - (\theta' + \theta'')$. But the sum of these angles is equal to $180° - \theta$; therefore $\theta = \theta' + \theta''$; or the angle at the centre of the earth between the two points A and B is equal to the angular depression of B as seen from A, plus the angular depression of A as seen from B.

Having explained how the angle θ may be determined theoretically, it now remains to show how the angles θ' and θ'' may be very accurately determined by means of the horizontal telescope.

Since the angles θ' and θ'' are necessarily very small, it follows that the telescope at A or B will be very nearly horizontal; and we shall suppose that the angles θ' and θ'' are less than one-half of the field of view of the telescope. Let us then suppose that we have a horizontal telescope at A and another at B. If the telescope at A be pointed directly at B, the axis of the telescope or line of collimation will be in the line AB, and pass through the horizontal axis of the telescope at B. Next let the telescope at B be made horizontal; the line of collimation will be in the line BA', and the telescope at A will be in the field of view at B. Then by means of a micrometer in the telescope at B, we bring the movable thread to bisect the eye-piece of the telescope at A, the reading of the micrometer screw will show at once the value of the angle ABA', or θ''. Next let the telescope at A be made horizontal. Its line of collimation will take the position AB'; and if the telescope at B be pointed at A the value of the angle BAB' or θ' may be at once read off by means of a

micrometer in the telescope at A, in the same manner as before with the telescope at B. Now, since the line AB is supposed to be known by actual measurement, if we find the angles θ' and θ'' as already explained, we have the means of computing the sides AC and BC, or the distances of the places of observation from the centre of the earth. We have thus indicated a very exact and convenient method of finding the angles θ' and θ''; but there are four independent methods of finding these quantities, which we will now explain.

The first method is by means of micrometers in the telescopes at A and B as already stated; the second method consists in measuring the heights AA' and BB' at which the respective lines of level from the points A and B pass above the axes of the instruments at B and A respectively; then dividing these distances by the known distance AB we get the tangents of the angles θ' and θ'', which ought to agree with the values found directly with the micrometers.

The third method of finding these angles is by means of graduated arcs of circles of long radius, attached to the instrument. These arcs need extend only over two or three degrees; and in instruments of great delicacy might have a radius of three or four feet.

The fourth method of finding these angles is by means of a delicate screw attached to the instrument as far from its horizontal axis as possible. Then knowing the distance between the threads of the screw and the distance of the screw from the axis of the telescope it is easy to find the angles θ' or θ'' corresponding to any number of revolutions of the screw that may be necessary in order to bring the axis of the telescope from the position AB' to AB. For example, suppose the screw has one hundred threads to the inch, and was three feet from the axis of the telescope; then one revolution of the screw would revolve the telescope through an angle of 57.″297.

The first of these four methods of finding the angles θ' and θ'' can only be applied to those cases in which these angles are considerably less than one-half the breadth of the field of the telescope; the second may be used for all distances at which it is practicable to measure the distances AA' and BB'. Our present knowledge of the magnitude of the earth shows us that, if the distance AB is equal to one mile, the distance AA' or BB' would be equal to about 8 inches. We also know that the distances AA', BB' are very nearly proportional to the squares of the distances AB. Therefore if the distance AB were four miles, the distance AA' would be 128 inches, or $10\frac{2}{3}$ feet; and if the distance between the stations were five miles it would amount to nearly 17 feet.

The third and fourth methods apply to any distances at which the two stations A and B are visible from each other.

We must now estimate the degree of precision which we ought to be able to attain by this method. If we measure the angles θ' and θ'' by means of the micrometer, we ought to be able to attain the precision reached by astronomers in their measurements of the angular distances between the double stars, since there is no reason why a system of luminous points resembling stars may not be arranged for observation at the stations A and B. Now astronomers, during the past hundred years, have given such micrometric measurements to the thousandth part of a second of a

degree, by single measurement; and have given the results of numerous measurements as correct in the fourth decimal of a second of arc. I do not place much confidence in the last two figures of such a decimal; but think we may properly assume that if we employ three decimals, the last only is doubtful. We shall therefore assume that, by means of numerous measures of the angles θ' and θ'', their values may be obtained correct to the third decimal place.

It now only remains to inquire what degree of precision in the dimensions of the earth might properly be expected from such measures as we have indicated. In order to answer this inquiry we may suppose that the distance $A\ B$ between the two stations is correctly known. If the sum of the angles θ' and θ'' amounted to just $3'\ 0''.000$, or $180''.000$, then an error of *five units* in the fourth decimal place of the angle would make a difference of only *one unit* in the *sixth decimal place* of the *log sine* or *log tangent* of the angle; and consequently such an angle would give the radius correct to six places of figures. Now, we know that the mean radius of the earth is about 3,958.80 miles; therefore, by means of an arc of three minutes of a degree, we ought to find the radius of the earth correct to within one or two hundredths of a mile, or within about one hundred feet of the true value. But the values of the mean radius of the earth, according to the determinations of astronomers, by means of large arcs of the meridian in different parts of the world, made during the last sixty years, differ from the mean of all by more than *one-third* of a mile; and those deduced from measures made during the past thirty years differ among themselves by nearly *one-sixth* of a mile. Therefore, if we can determine the values of θ' and θ'' correct to even the *one-hundredth* of a second, we can determine the earth's mean radius from an arc of *three minutes*, by this method, with as much precision as we can by the methods generally used by measuring an arc of *three degrees*.

By means of two stations we are enabled to determine the radius of the earth with very considerable precision, on the supposition that it is a perfect sphere; but in order to determine its form we must first determine the angles between three stations. Since three complete observations of a planet or comet enables the astronomer to determine the form, position, and magnitude of its orbit; so in like manner three complete observations of terrestrial stations enable us to determine both the form and dimensions of the earth. Observations made at stations near each other would, however, determine the elements of the osculating spheroid whose surface passed through the places of observation, and might differ considerably from the elements of the mean spheroid which would best represent the surface as a whole.

If the two stations were situated on the same parallel of latitude, the difference of longitude between them would be given by the equation

$$\sin \tfrac{1}{2}\,\alpha = \frac{\sin \tfrac{1}{2}\,(\theta' + \theta'')}{\cos \varphi};$$

in which α is the difference of longitude and φ is the latitude of the places of observation. From this equation it follows that at the equator where $\varphi = 0$, the difference of longitude can be determined with the same precision as that of latitude.

ENGINEERING AND SURVEYING.

By Charles Latimer, Member Civil Engineers' Club of Cleveland.
[Read July 12, 1887.]

This is a broad subject; I had intended to entitle it "Progress in Civil Engineering and Survey," but upon consideration of the works of ancient times and the evidences of remarkable ability displayed therein, it seems doubtful whether we have made the advances with which we credit ourselves. We do not bestow a tithe of the care upon our structures that the architects of old did on theirs, and it would seem that the ancient surveyors knew more than we of the measures of the earth.

When we study the ruins of ancient grandeur and of lost empires, we realize that our civilization is but a revival, and many of our inventions only discoveries in the mines of the past. The ancient Egyptian recited no fable when he spoke of the lost Atlantis. As we set out on our journeys of discovery we do well to note carefully the ancient landmarks and delve for wisdom in the buried years.

When we glance at the ruins of Egypt, of Central America, at the wonders of the world, at the City of Babylon, covering at the lowest computation a space of 100 square miles, nearly five times the size of London, with its walls, according to Herodotus, 335 feet in height and 85 in width; with its hanging gardens laid out upon a series of arches 75 feet in height and covered with trees and flowers, we look in vain for anything of the present day to surpass them.

Of ancient aqueducts, some of those of Greece supply Athens at the present day. Of Roman aqueducts, the Porta Maggiore and the aqueduct at Nismes, now called the Pont du Gard, are the most celebrated. The Porta Maggiore was an aqueduct bridge forming an archway over which water might pass, and below which traffic could be conveyed. In one place the chain of arches reached a height of 109 feet, but this must yield the palm to the Pont du Gard, which rose to 180 feet. In Spain we have the famous aqueducts of Segovia and Tarregona, the former 2,400 feet long with 159 arches in two tiers, reaching a height of 102 feet. Perhaps more wonderful, though less known, are the subterranean cisterns under Constantinople. Beneath the city, and far beyond its boundaries, extend labyrinths of water-ways, passages and prisons, of a length and direction apparently undiscoverable in the present day. The citizens may be said to walk not so much on terra firma as on a continuous roof. These subterranean channels date from the times of Arcadius, Theodosius and Constantine; the roofs are arched, supported by pillars with exquisitely carved capitals. There is an air of mystery surrounding these unpenetrated halls of waters. Many years ago a rash young Englishman set out in a little boat on a voyage of discovery, though warned by his friends. He bade them good-bye, laughing gaily and telling of the wonders he should have to relate when he should return, but he was never seen again.

There is in Egypt a remarkable hydraulic work, the lake of Mœris. M. Linant, a French engineer, was the first to determine its character.

The object of its construction was to regulate the irrigation of the Feiyoom, and it should be called a reservoir rather than a lake.

But not man alone, but the workers in the insect world, can bring us down from our pinnacle of vaunted superiority. The bee is a mathematician of a high order, and understands protoplasms better than Darwin. He understands stowage, too, better than any ship captain. He makes the roof of his cell with three convergent planes, each one exactly 70 degrees, or 110 degrees convergent, and throughout, the cells for drones and for female workers are precisely the same size. He makes and stores his cells in hexagons of perfect form, both for strength and stowage. He uses his sucking apparatus as if he understood the laws of atmospheric pressure.

The ant is no insignificant engineer. Ant hills in America are constructed as cities four square, and in Africa, we are told, ants build mounds of great size and regular form. The ant is an example to many of us in the engineering profession who are somewhat lacking in activity, and we would do well to take the advice of the Scripture, "Go to the ant, thou sluggard." The beaver is a good pile driver and house builder, as well as plasterer, and makes careful surveys. We might learn much engineering skill from studying the habits of animals. Jeroboam was Solomon's engineer, and we know that Solomon wrote many books upon plants and natural history, and I have no doubt that his engineer profited by the knowledge. We have read of "King Solomon's mines." Perhaps we might get a lesson in mining engineering from that many gifted sage.

A friend of mine has invented seven aerial ships and he has made a study of the eagle. If any of you want to invent a flying machines, go to the eagle or some other bird. If you want to invent a first-class diving apparatus, go to the fish. How many engineers who plan an invention overlook what has been done. I have often noticed this lack of observation. We have all known instances of inventions made or adopted by engineers, when almost the acme of perfection in that line had been reached, and what appeared to be a new invention, was but an inferior adaptation of the earliest stages of knowledge. We would ridicule the mechanical engineer who should ignore the fact that locomotives existed now and should build one of rude form. Yet as great instances as this of folly in making inventions have occurred from lack of observation. But if, as Solomon said, "there is nothing new under the sun," we have a wide field for the talent of the engineer in making new applications of old principles and methods. Many a man has made money and reputation by adapting the principles of another's invention, when the originator passed away unrewarded and unknown to fame. Probably the greatest field to-day for engineering talent is in developing methods originated by others but never wrought out fully.

A mark of a great engineer is to undertake things considered impossible by his fellows. Many great engineering projects have been accomplished by men who were not engineers. De Lesseps was only a diplomat, but he conceived a great engineering scheme, and by his determination and industry he cut the tongue of the Egyptian sea. Now he proposes to sever the continents of North and South America. Time will

show whether here he is an engineer or an adventurer. Eads, who built the iron clads of the Mississippi, who spanned that river with a magnificent steel bridge, who made the port of New Orleans navigable for the greatest ships of the world, and who conceived the stupendous thought of carrying ships like the Great Eastern across the Isthmus of Tehuantepec on wheels, was a manufacturer of steamboats and mechanical engineer of the firm of Eads & Nelson, of St. Louis. He had a great engineering mind truly, but it required the calculations of a Chauvenet and a Flad to enable him to put up his bridge, of a Lewis to locate his line, of a Williams and a Corthell as engineers at the jetties as well as at Tehuantepec. Some men are born engineers; Stephenson, for example. And we may well revere them as the ancients did their heroes, for it would seem as if Providence had brought them forward at certain crises in the world's history to accomplish great works. We think with astonishment of the knowledge of a Newton or a Laplace who could tell us to the fraction of a grain how much a pound on the earth would weigh in the sun or any planet, and who calculated and reduced to such a perfect system the motions and periodicity of the heavenly bodies that the navigator to-day can tell to a small fraction of a mile the position of his ship with as much certainty almost as we can calculate the position of a train as it passes over the earth.

If I were to recount the engineering schemes of to-day, I should simply have to repeat, for the most part, what has been said by the presidents of various engineering societies and others in their addresses, yet at the risk of repetition, I must mention some. One of the most remarkable changes in the engineering of the day has been introduced by means of electricity, and another, by the discovery of natural gas. A positive revolution is taking place in our methods of construction and of manufacture, and it occurs so rapidly that we are not able to take it in.

At the beginning of the present year there were about forty parent companies selling electric light apparatus in the United States. The total capital invested in producing the apparatus and in supplying the light locally is estimated at from $100,000,000 to $125,000,000. There are about 700 local electric light companies and about 100 gas companies also supplying electric light. About seven years ago I used sometimes to go to see Mr. Brush in a little shop where he was making experiments with his electric light we all know the wonderful development that has resulted from his work. About the same time, the system of Edison came into vogue, and in 1886, Edison had 702 plants; he has probably 1,000 to-day. There are over 750,000 incandescents in this country, and about 100,000 arc lights are burning nightly. In 1886, incandescent lights fed from secondary batteries were introduced on several railroads in New York and New England, and the work is growing.

Forty-eight years ago in Washington City I saw a train run by electricity, the invention of Professor Page, of Washington. It ran round a circle and was a perfect success. The only difficulty was the cost. The cost of furnishing power for electric railways now does not exceed $2.50 to $3 per day per car, while the total cost of horse-cars per day is from $6.50 to $9.50. The total of passengers carried in 1886 by electric street railways in the United States was over 1,000,000. The rcads now in con-

struction will double these figures in 1887. There are now from ten to twelve electric railway systems. Europe has eleven electric railways, all built within three years. The first in operation in this country was at Chicago, February, 1883, with 400 feet. I have no doubt that the heating and lighting of railroads throughout the world will be accomplished by electricity in a short time. I think that one of the great uses of electricity will be in mining engineering, the power being transported from turbine wheels to great distances, small electric wires carrying it from the dynamo right to the motor at breast of the tunnel. This will be specially useful in places where water-power cannot be obtained. This would seem to be a simpler method of handling electricity than by carrying air in pipes. The use of electricity will enlarge the work of engineers, and they must bring their minds to a consideration of its uses.

Almost simultaneously with the developments of electricity have come the discoveries of natural gas. These have been treated extensively by our engineers, yet the gas engineer has scarcely arisen, he is scarcely fledged. The perfecting of drilling and the piping to great distances are questions of the utmost importance to the engineer. Economy in using the substance and its multiplication by mechanical appliances are problems not yet solved. A 15,000,000 well, the roar of which can be heard from 15 to 20 miles, has been many times duplicated, but the subject is yet in its infancy, for all the holes bored for gas throughout the country would not fill a house lot on Euclid avenue. We can afford to give this planet a good deal more ventilation yet. The use of this substance has brought down the price of oil, and in seeking for gas large quantities of oil have been found. This brings us to what we have long foreseen, the use of oil in locomotives. Years ago I called the attention of the master mechanic of the Erie to the certainty of the use of oil in this way, but it is only within a few days that it has been accomplished practically. It cannot be long before railways are equipped with oil fuel locomotives, and the destruction of the fine parts of the machinery and the discomfort of passengers from coal cinders will vanish.

I am glad to be able to state that the railroad construction in the United States for the first six months of this year shows a probability that the total construction for 1887 will be as great, if not greater, than in any year since since the inauguration of railroads. In the past six months tracklaying has been going on in 37 States on 136 lines, adding 3,754 miles of main track to our railway system. This is a larger showing of new construction than in any previous year except 1882, when nearly 5,000 miles were laid in the first six months, and 11,563 in the year. The returns for the first half of 1886 were only for 1,755 miles, while the work of the year was about 8,500 miles. The railway system of the United States now aggregates 141,300 miles.

Among the great railway projects of the day is one along the Congo River, in Africa. A party has been sent from Belgium by the Congo Company to make an examination of the river and to specially survey a route for a railway round the cataracts, which extend for over 200 miles. This seems like the beginning of a movement for opening up the interior of Africa. It is announced that the Chinese Government will soon begin to construct a railway from Tientsin to Pekin and has asked

bids for the work, which is to be finished in two years. Railroad construction is going on in Brazil and other parts of South America, though the conditions there are not so favorable and the extension is slower than in this country.

A road is now under construction in Japan which will give continuous communication of some six or seven hundred miles, with side branches additional. The railways generally run parallel to the mountains and alongside the sea. The steepest grade in crossing the mountains is 1 in 40. The engines for the Japanese system are built in England, though the cars are now made in Japan.

Hawaii now has twenty miles of 3-foot gauge road, and Maui, fifteen miles. Seventy miles more will be built and equipped with American rolling stock.

Russia is constantly organizing plans for a comprehensive system of new lines. A road has been planned from Drenburg, in the southwest, across Siberia via Tobolsk and Lake Baikal to North China and the Pacific. Only scraps of these have been built and their outcome is doubtful. A road is soon to connect Astrakhan with Central Asia, which will bring the industries of Turkestan, Afghanistan, and Persia yet more under Russian influence. The Russian Government, seeing the abuses connected with private management of roads, has increased its influence over existing lines, and all roads now in process of construction, are state roads. By a general railroad law of June 12, 1885, an attempt has been made at a uniform regulation of all traffic on public and private roads. In accordance with this a railroad commission has been appointed with power to examine and in some cases to control.

In the line of surveying the use of stadia now renders preliminary surveys cheaper and more rapid, so that a preliminary estimate may be now made with one-fourth of the time and cost of previous days. The method recently explained to us by Professor Stockwell, of using the telescopes for measuring angles or distances upon the earth, should enable us with more economy and greater rapidity to measure latitude and longitude. But not only can we survey the surface of the earth; the interior also may be explored, and I trust that I may be pardoned for alluding to a subject which has been so interesting and valuable to me. About ten years ago I wrote substantially as follows to Mr. Rossiter Raymond : "I now say that the time is not far distant when we can survey the interior of the earth and discern the substances in it as accurately as we now do its surface." Mr. Raymond, in answer to this, not long ago, undertook to ridicule the whole subject and to teach the public what I did not know. It is surely a great mistake for any one to undertake to teach on a subject of which he has no experimental knowledge. This, of course, is personal, but as I have already appeared on this subject before you, I have reason to believe that it will not be devoid of interest for you in more extended lines. I bring you here a chart of a territory that I have lately surveyed. It is a coal territory that I laid out, though I did not see it with my eyes. Many holes had already been bored and the coal found, but of this I knew nothing. I was taken to a hole which was being bored, and was asked if coal could be found at that point. I said that the coal would be found at 226 feet,

with a thickness of four feet. I afterward visited some 12 to 15 points, and gave depth and thickness correctly where holes had been bored. I was then informed that coal had been found at the place first visited, and that the depth and thickness given by me were correct. In all but two instances I was correct. The mine as you see it on the map was outlined by me for a distance of more than a mile and a half. Time will prove whether my outline will be found correct in all particulars. It is therefore for examination at a future day. If any one should desire further information upon this subject, I can refer him to the parties who accompanied me. Now, this surveying of the interior of the earth is either a fact or it is not. If it is a fact, then it is well worthy of your attention as engineers ; if it is not, then the sooner the fallacy is exploded the better. For my own part, I have no doubt that it is a truth and that it is in the power of man to discern metals, coal, gas, water, in the interior of the earth without the aid of the eye or the use of transit or level, though these are important as adjuncts in indicating the surface lines. I have not attempted in this brief paper to treat the subject scientifically, but simply wish to give you a thought or two for your consideration.

I have thrown out these few thoughts for your consideration with the hope that they may elicit some useful discussion ; if so, I shall be well repaid for the brief time that I have been able to give to this paper.

DISCUSSION OF MR. CHARLES LATIMER'S PAPER.

At the conclusion of which he exhibited a map of a coal-field that he had surveyed by the indications of the divining rod.

Mr. Varney: From what Mr. Latimer has said it would appear that the parties accompanying him knew the depth and thickness of the coal, though he did not, except by the test of his mind. The truth of his statements was verified by these parties. Would it not be possible to account for these facts by the supposition that he obtained his knowledge from the minds of the people with him.

Mr. Latimer : I have made experiments both with people who knew the facts and with those who did not ; I think I may say that I have more often been correct in the former case. It may be that an impression has been conveyed to me from the minds of those with me, but in this case I came to a hole where I gave the thickness correctly, but they said that my depth, 237 feet, was wrong, that the coal had been struck at 250 feet. Upon examination afterward, it was found that the coal had been struck at 236 feet; therefore, if I had obtained my knowledge by mind reading I would have been 14 feet in error, whereas I made only a mistake of one foot. Five years ago, accompanied by Professor Harding, of the Brooks school, and one of the gentlemen who was with me at this last trial, I went over a coal territory two miles and a half from this one and blazed the trees with an axe. Two years after, I went over the same ground with the superintendent and remarked : "You have taken out the coal." He replied that he had and showed me that it had been found at the spots that I had blazed. I have been mistaken both when there

were persons with me who knew the ground, and when I have been alone, and I have made accurate tests when alone and in company. I believe that the mind does perceive what is beneath the surface.

Mr. Varney: With regard to a statement in the early part of your paper, how nearly did you say that a navigator could locate the position of his ship?

Mr. Latimer: I could locate it within 600 feet. I would not do it with a lunar observation, but with a chronometer and sextant.

Mr. Varney: Do I understand you that it is the practice with seafaring men to locate as closely as that?

Mr. Latimer: No; about a quarter of a mile is usual.

Mr. Sargent: The condition of the sea would make some difference.

Mr. Latimer: Certainly; it could not be done in a gale of wind or without a clear horizon.

Mr. John Walker: Mr. Latimer is the second person whom I have known who has made use of the divining rod. In Baltimore I had a well-digger go over some property and mark the spots where there was a strong influence of water. When he had so marked them he gave me the twig to see if I felt the influence. At first the twig made no movement, but afterward it turned over the strong water streams. We found abundance of water at the places indicated. By way of experiment I had a well dug at a spot that he said was barren, and no water could be found there.

Mr. Searles: Did he tell you in advance the depth at which it would be found?

Mr. Walker: Yes, sir.

Mr. Searles: It is very gratifying to me to see this method of investigation taken out of the realm of the magical and placed among the verities of science. In ancient times it was known that a piece of amber when rubbed would attract substances to itself, and that was the origin of our knowledge of electricity. So this mental action by which, under proper conditions, substances below the surface of the earth may be discerned, though it is little understood at present, may lead to great discoveries in the future. The action of mind upon mind has been studied by the so-called "mental philosophers." But it is only within the present century that mind has been studied from a scientific standpoint, as if it were a machine. In this case, as Mr. Latimer has said, though a simple twig is held in the hand as an indicator, the action is in the mind of the operator. I am told that the operation is very exhausting. It is no child's play to locate a vein of coal below the surface of the earth. You will observe that the depths given for the coal vary greatly, but the profile shows an almost horizontal body of coal. So far as the drillers have yet penetrated, with perhaps two exceptions out of nearly a score, all the depths given are correct. It would appear, therefore, that there is a system that may be reduced to a scientific basis. It seems to be worthy of serious consideration, and much may be developed from it. The societies for psychical research in London and Boston are doing a very important work in collecting facts with regard to various sorts of debatable phenomena, proving them to be facts, classifying them and putting them upon record.

Mr. Sargent : Did Mr. Latimer notice any difference in the action of the twig over different substances, as coal, gas, or iron ?

Mr. Latimer: None whatever. The mind appears to discern.

Mr. Baker: It appears strange that as the depth in most of these cases was correct, as well as the thickness, that there should be any errors. It seems that there may be some truth in Mr. Varney's idea of unconscious mental influence from those present, or perhaps knowledge derived from geological observations may be an assistance.

Mr. Latimer: Mr. Rossiter Raymond, who without any experimental knowledge on this subject, ridiculed it, has lately written a little pamphlet on "indicative plants," which I would recommend to your attention. He quotes Agricola with reference to the natural discovery of veins by observation of the plants and trees above them. He gives an instance of an iron ore vein in Germany, near Siegen, which can be traced nearly two miles by birch trees growing on its outcrop, while the remainder of the country is covered with oak and beech. When I was last at the coal mine in Youngstown, I asked the superintendent if he had ever observed any peculiarity in the vegetation above coal veins. He said that he frequently noticed that tansy grew there. A German came into my office the other day and informed me, that knowing that I was interested in such subjects, he wished to call my attention to the fact that above gas or oil veins a certain brown grass flourished. He did not know its name. I did not recognize it from his discription, but will look for it. I think it is advisable to study every indication, though in locating veins I have depended entirely on the action of my mind.

Mr. Walker : Persons who have paid attention to it can tell the quality of the ground on which various kinds of wood have grown, even after the wood has been used for furniture. Ash, for instance, will be more closely marked the tougher the ground has been.

Mr. Sargent : There is one thing that seems to militate against that theory of indicative plants. When vegetation of one kind has been cut off another kind succeeds. In a district on Lake Superior, where nothing but evergreen had grown, after the fires had swept away the vegetation, a thicket of white birch came up. Pine has been swept away and oak has succeeded it. The second growth would appear to have sprung from seed that had lain dormant.

Mr. Latimer : The chemical changes in the ground induced by the fire probably made it more favorable for the growth of a different vegetation.

Mr. Searles : As it seems to be proved that distances can be determined vertically downwards by the method described by Mr. Latimer, would it not be possible to determine distances horizontally in the same way?

Mr. Latimer : A pretended adept on this subject claimed that he could locate a mine without going near the place, and could in the same way tell where water could be found. I do not consider that legitimate or possible, neither would I expect to be able to give a distance horizontally.

Mr. Searles : As one mind can act upon another at a distance, why might not an impression be received from coal at a distance also? The impression is received from a distance vertically downwards ; why may not the same thing be true when the vertical line is changed to the horizontal?

Mr. Baker: Did Mr. Latimer ever locate a field of coal or any other mineral, and give an estimate of the depth and thickness of veins before any drilling was done? If so, was the indication afterwards proved to be correct?

Mr. Latimer: Yes. I once located a place for the gentleman for whom I made this map. The vein had been lost. I marked the spot were it would be found, and gave the depth as 235 feet, thickness of coal 5 feet. It was marked plainly at the time on a map, and the coal was afterwards found exactly as I had predicted. I have done similar things many times.

Mr. Whitelaw: How much further will the Rolling Mill Company have to drill before they find gas?

Mr. Latimer: I think the gas is close below the bottom of the tools. There is a rock pressure now of about 500 pounds. The gas comes up through 800 feet of water, and below that it has to ooze past the tools, which fill the bottom of the well to about 50 feet. There is also 10 feet of whipstock. The rod indicates that the gas will be found at about 3,360 feet at farthest.

HYDRAULIC MOTION.

By Samuel McElroy, Member of the Western Society of Engineers.

[Read May 3, 1887.]

The anomalous condition of the science of hydraulic flow at present, is quite evident to those who are required, from time to time, to apply received formulæ to experimental results. While, in some cases, close correspondence occurs, in others there are serious discrepancies, and the causes need close study.

It must be admitted that experimental tests, which form the only true basis of any theory, have been much neglected, or conducted at times on a very inadequate scale When we see a profound student like Weisbach, correcting the conclusions of Coupiet, Bossut and Du Buat, with tubes of 1.06 to 5.31 inches diameter; or Messrs. Humphreys and Abbot, with all the Government appliances at command, abandoning actual observations below certain depths to show their faith in the parabolic theory of velocities on a fluctuating river of enormous section, we find much to regret; nor is it more comfortable to find formulæ frequently modified to suit special experiments.

Since our usual formulæ assume certain laws of motion, as applied to channels and pipes, in cases where dissimilar modes of motion may exist, which are not carefully presented by our usual authorities, the object of this paper is to discuss the general principles of hydraulic motion, as furnishing the true guides to experiments and formulæ, under the following heads:

Practical Illustrations of Flow.
Four Modes of Water Motion.
Received Theories.
Tests of Theories.
Conclusion.

PRACTICAL ILLUSTRATIONS OF FLOW.

This paper not being intended to discuss hydraulic experiments or their formulæ, a few illustrations of relative comparison will be given, in connection with the main argument, as to pipes, races, canals and aqueducts. For convenience and simplicity, the comprehensive Chezy formula $V = C\ \sqrt{RI}$, with Weisbach's co-efficient, 92.66, is used as a basis in some cases mentioned.

Pipes: Rochester—Feeding mains of wrought iron, 50,776 feet 36-inch, 27 feet fall, with various bends, reducing into a 24-inch 51,495 feet long; fall, 116.72 feet; discharge into Rush Reservoir, prism measurement, with no allowance for absorption on a new wall, 9,292,800 gallons, 14,378 cubic feet per second; velocity of 36-inch, 2.034 feet per second; 24-inch, 4.577 feet. As analyzed by Chief Engineer Tubbs (Annual Report, Jan. 1, 1877, p. 63), the increase over usual formulæ was: Prony, 37.97 per cent.; d'Aubuisson, 37.35; Weisbach, 25.52; Eytelwein, 25.25; Grashof, 25.01; d'Arcy, 16.83; Lampe, 6.41.

Brooklyn pumping main (1859): 36-inch, 3,450 feet long, 3.018 feet per second; two check valves, one curve 800 feet radius; mean frictional head, 4.71 feet; co-efficient, 94.34.

Fanning (Hydraulic Eng., p. 254): For a pipe under same head and length, one foot diameter, 10,000 feet long, velocity by Du Buat, 3.978 feet per second; D'Aubuisson, 4.78; Prony, 4.842; Chezy, Jackson and Leslie, 5; d'Arcy, 5.464, or 37.2 per cent. extreme range. Constant used by him (p. 238) for 20-inch main, 26.16 feet head, is $v = 110.628 \sqrt{R\,I}$, or about 19.39 per cent. above our 92.66.

Mill Races: Where penstocks are making variable drafts on a race, negative first order waves are produced, and bottom or side velocities frequently exceed those of the surface; other causes may produce similar results.

Lowell (Francis). Flume 10 feet wide, about 8 feet deep; mean velocity, 3.98 feet per second; channel velocities were irregular; mean surface velocity, about 6.28 per cent. less than flume mean; sides sometimes exceeded central velocity. Flume 20 feet wide, central 2.9 to 4.3 per cent. above section mean velocity; discharge by weir; slope not reported. (Lowell Hyd. Expts., pp. 149–153.)

Hydraulic Canal, Niagara: In a number of observations made for an expert case, a section 450 feet long, 37.13 feet average width; average depth, 8.75; slope, .00024; wet perimeter, 55 feet; the mean velocity was low, 2.5 feet per second, giving a constant of about 70. Bridge obstructions and side and bottom irregularities occurred on a line of about 4,000 feet, but the low results were a surprise to me.

Erie Canal.—In 1841 Eytelwein's formula ($R\ I = .000024265\ v + .000114155\ v^2$ feet per minute), was used by Division Engineer O. W. Childs to determine the difficult problem of the Western Division supply from Lake Erie, for about 62.5 miles. Tests reported in 1878, by Division Engineer W. H. Searles for section at Lockport of 693.68 square feet (assumed 643.68, or 7.7 per cent. increase); surface width, 96.46, as assumed; fall in 62.5 miles, 3.165 feet (assumed, 3.068); discharge, actual, 33,755 cubic feet per minute (calculated, 25.450), or 32.3 per cent. increase.

In the Croton and Boston reports Mr. Jervis states that Erie Canal feeder experiments show an excess over the formula.

Aqueducts—Croton : From the first observation of 1842 the flow, with a shallow depth, was assumed at 15 per cent. increase. With a depth of 2 feet, the following table makes the increase over the Chezy constant 35.69 per cent.

This table is based chiefly on Chief Engineer Newton's report of February, 1882, giving depths at Sing Sing, and flow at various dates from 1868 to 1881. Aqueduct section, semi-circular arch : Diameter, 7.416 feet; chord width, lower segment, 6.75 feet ; height, 8.46 feet, internal ; slope, .00021. The deduced velocities make it evident that the statement of flow can only be taken as approximately correct :

CROTON AQUEDUCT FLOW.

Depth.	Square feet section.	Wet perimeter.	Velocity. Formula.	Velocity. Experiment.	Per cent. increase.	Mean hyd. radius.	$\sqrt{RI}$	Cu. ft. per second.	Gallons per day.
a2′	11.98	9.50	1.507	2.045	35.69	1.261	.01627	29.279	18,924,000
3.5	23.23	12.53	1.828	3.192	74.61	1.854	.01973	74.168	47,937,000
5.01	33.53	15.57	1.970	2.99	51.78	2.153	.02126	100.274	64,810,000
5.50	37.26	16.61	2.01	3.038	51.09	2.242	.0217	113.193	73,617,000
6.	40.82	17.67	2.04	3.115	52.68	2.310	.02202	127.163	82,189,000
6.26	42.57	18.15	2.037	3.115	52.92	2.304	.02199	135.606	87,646,000
7.02	47.40	19.93	2.070	3.166	52.94	2.378	.02234	150.084	97,004,000
7.35	49.34	20.81	2.067	3.152	52.49	2.371	.02231	155.567	100,541,000
7.50	50.06	21.16	2.064	3.104	50.38	2.365	.02228	157.421	101,746,000
7.62	50.64	21.54	2.06	3.134	52.13	2.351	.02223	158.709	102,758,000
b8.46	53.35	26.66	1.902	3.392	.....	2.007	.02053	181.	115,000.000

a Report, August 2, 1842.
b Report Chief Engineer E. H. Tracy, September, 1873.

Boston : Aqueduct oviform, 5 feet base diameter, 6.33 feet high; slope, 0.264 feet per mile ; fall in 14.627 miles, 4.26 feet ; estimated flow at 46 inches depth, in 1844, 7,109,000 gallons; in 1845 (Jervis), 8,305,000 ; actual, 1853, 10,346,300; 45.39 per cent. increase. In 1863, under 16 inches head, the flow was taken at 16,500,000 gallons.

Dorchester Bay Tunnel Sewer : 7.5 diameter; length, 7,160 feet, constant August 26, 1886, 117.78 ; September 25, 121.46 ; October 20, 107.45. (*Eng. News*, 1887, p. 208). Not half full, with considerable velocity and sewage flow, may in part explain a low constant.

Washington : Main aqueduct, 9 feet diameter, in brick ; part in masonry, 9.75 feet ; 1,880 feet inlet in rock tunnel, about 11 feet diameter ; length, 56,090 feet ; slope, .00002042 for 1.36 feet hydraulic head, aqueduct submerged ; flow (1881), 26,754,000 gallons, 41.388 cubic feet per second ; constant, 96.006.

The slope of the main aqueduct is .00015, and with even so flat a slope as above indicated, the discharge seems very low. In the expert case of 1862–63, estimating capacity for flow, with different depths of conduit,

Mr. Slade and I did not feel at liberty to apply the full ratio of the Croton and Boston aqueducts. During the examination an experiment was submitted by General Meigs on a depth of 3,465 feet; observed velocity, 2.3084 feet per second, assumed at 1.939 mean; slope, .00015; constant, 115.63, or about 24.78 per cent. over our 92.66, the discharge being 43,628 cubic feet, against 41,388 in the surcharged case.

Brooklyn: In the design of this aqueduct in 1856, I studied carefully the plans of Major Douglass for the Croton, with an increase of nearly 50 per cent. in section. The low sources of supply, close tide level and need of great economy in a project strongly opposed, obliged me to reverse the section, as to its principle of flow, for a width of 10 feet; height of 8.66 feet; section, 73.46 square feet, Croton being 53.35.

From experiments made for the Extension, proposed dimensions, 8.146 feet width, 6,917 feet height: flow depth, 5.25 feet; flow area, 43.859 square feet; wet perimeter, 18.633 feet; R, 2.3537; I, .0001; calculated velocity, 2.0809 feet per second; flow, 91.2662 cubic feet; the constant is 135.65, or 46.37 per cent. increase. The details of the experiments have not been published. From notes in my possession I have no doubt the main aqueduct for 5 miles from the pump well would show, at not less than 5 feet depth, about 60 per cent. increase.

FOUR MODES OF WATER MOTION.

Water, in wave form, appears to have four modes or orders of motion. The first order, in which there is a wave motion through a mass of particles, by their successive vertical, or nearly vertical, displacement, shown in the addition to any body of water, in motion or rest, of a special supply or any special impulse, and the transmission of the addition or motion created by impulse through that body; the ocean tide wave, a river flood wave, a canal lock wave, the surge of a boat hull, or any protrusion of a solid body or impulse, as from a strong wind; waves of air, sound, light, heat, and electricity illustrate this action; it is the great primary law of liquid and fluid motion.

The second order, in which all the particles move on with the wave; shown by the surf wave, that of a channel in uniform motion, and any wave of translation where the particles are themselves delivered.

The third order, where the wave itself moves on through the particles, with a circular or elliptic motion of the particles, which return to nearly their original position during and after its passage; shown in the ordinary sea swell, pond ripples and like cases, where the impulse does not carry the particles with the wave.

The fourth order, in which the wave is stationary, and all the particles move on, shown in weir chutes, rapids waves and eddies caused by stationary obstructions, jets, fountains, cascades, vibrations of fixed cords, or grain fields, and like cases.

Waves of the first and fourth order are solitary in *character*, negative or positive in *species*. The first may be either "forced" or "free" in *variety*, controlled in speed by a continued impulse, or moving under its own laws, after generation; the fourth are "forced" in *variety*.

Waves of the second and third orders occur in groups and are "gregarious" in *character;* they have crests and hollows, and are "positive"

and "negative" in *species;* they deliver impulses, under their own laws of flow, and are "free" in *variety.*

The "lines of motion" in the first order are *parallel*, in the second, third, and fourth are *curved.*

Their *form* is defined by their surface slopes or contour; their *amplitude* by the length of this slope or body; their *volume* (in the first, second and third orders) by the number of particles displaced by each; their *period* by the time occupied in this action; their *height* by the projection of the crest above the surface in repose.

To a greater or lesser extent, in every body of water in motion these four orders of waves may be found, and of these the first obeys the primary law. Following Russell's analysis, here used, a further explanation of this wave may be given.

Seeking in vain to explain tidal motion by received theories, La Place foreshadowed the opinion announced by Dr. Whewell (Phil. Trans., 1833, p. 212), that there was "a horizontal fluid motion, extending to the bottom of the ocean, with a velocity equal to the fall of gravity." But these profound students left it to one of our own profession, in 1838 and 1844, to demonstrate its existence and laws.

In his report to the British Association, John Scott Russell, C. E., presents a careful and conclusive experimental analysis of this wave, which furnishes the only adequate explanation of its motion, and is now implicitly accepted.

In the experiments made with water troughs, three modes of wave genesis were employed; one, by horizontal displacement of a given quantity at one end; one, by the descent at one end of an equal quantity of water into the water at rest; one, by dropping a solid of equal contents into the water at one end. The results were similar in each case, and a close demonstration made, that the "mechanical power" supplied at one end was faithfully transmitted by the wave to the other end with a velocity regulated by the depth of water. The law of motion thus found was demonstrated on much larger bodies by Mr. Russell, and subsequently by d'Aubuisson and various other authorities of high rank.

Under this law, by means of a continuous series of waves or a single wave of continuous action, the generating impulse is carried through the more quiescant and ponderous body with a speed regulated chiefly by its depth, and a volume regulated by its impulse, and continually takes up vertically, and forces forward a certain mass of water, until its speed carries it beyond this mass to the next, which it takes up and advances by like displacement until the final point of actual discharge is reached and a delivery takes place; or, in case of obstruction, an impact and reaction equal to the generating impulse, less the degradation due to friction and other losses, which are small compared with those of waves of the second and third orders.

In this way great velocities are practicable without great mechanical work; that of a tide wave of 828 miles per hour, as in the South Atlantic, being 1,214 feet per second. It is motion through masses of mobile particles where that of the particles themselves, with any proximate speed, is impossible, and the transmission, with this speed, of a body of water equal to that which generates the wave, or to the generating impulse, less the incidental losses *in transitu.*

In the Black River Flood case against the State of New York, the destruction of about $750,000 value in dams, mills, tanneries, etc., along the entire river, in 1869, was distincly demonstrated by Messrs. Scott Russell, McAlpine, Haswell, Mills and myself, as the action of such a wave, liberated from the North Branch reservoir, at a height of 1,576 feet above the mouth, by a defective dam, at the culmination of an unusual natural flood.

The general formula for this wave is :

$$v = \sqrt{\frac{2\,g\,d}{2}} \text{ or } = 5.6694\ \sqrt{\text{depth}}.$$

RECEIVED THEORIES.

The usual formulæ for conduits and channels in practice refer chiefly to waves of the second order, of which the usually received theory of motion may be thus stated :

The general laws which affect the uniform motion of water in a channel, where the particles themselves are carried along, have long been understood.

That liquids transmit pressure in all directions when at rest, and vary it under conditions of motion : that the pressure due to gravity is affected by the atmosphere, is also as the depth or the impulse, and that action and reaction are equal : that in a channel "in train," or state of uniform motion, the motive power is gravity, the action results from the extreme mobility of particles, and the retarding forces which balance the acceleration of gravity are frictional resistances of the wet perimeter chiefly, suspended matter, viscosity, winds, and other forces ; that under certain conditions moving water tends to form parabolic or other regular curves, are familiar principles to all engineers.

Du Buat's theory of 1786 assumes that water molecules of "inconceivable tenuity, perfectly hard and polished," friction not influenced by pressure, "introduce themselves into the pores of the wet perimeter," and "form the surface on which the whole volume flows." "Different materials of perimeter do not affect intensity of resistance;" perimeter "resistance proportional to square of velocity, when molecular spaces are completely filled, viz., at low velocities ; filling up diminishes as velocity increases and resulting resistance decreases ;" perimeter "resistance communicates itself to the whole mass, and result, for each molecule, is in direct ratio to the perimeter and inverse to sectional area. At equal inclinations velocities would be as square roots of area to perimeter, if this proportion were not altered by attraction of perimeter on neighboring molecules ; this extends to the same distance in all channels. As each molecule experiences a resistance in inverse proportion to its distance from the perimeter, their velocities vary according to these distances, and they tend to separate continually ; part of the accelerating force is employed to overcome the reciprocal attraction which opposes this separation.

Prony's theory of 1804, assumes :

"When water is flowing in a canal or pipe, a thin lining of fluid particles adheres to the interior surface of the pipe or channel, and does not partake of the general motion. This *stationary envelope* opposes to the

particles immediately in contact with it a resistance arising both from adhesion and from a sort of friction, different from that which is observed at the contact of solid bodies, and which by means of this adhesion is transmitted from the outside to the interior of the stream. * * * The velocities then in different points of the same transverse section are not the same." (Storrow, Water-Works, p. 20.)

The same theory of "uniform" channel motion is thus expressed by General H. L. Abbot:

"When water is moving uniformly the accelerating are equal to the retarding forces. The former, in a straight channel, are measured by the product of the weight of water into the sine of the slope of its surface. The latter arise from the joint action of two forces, adhesion to the bed and cohesion of the different particles of water to each other. The first is evidently the primary resistance, the second being rather a force which regulates the distribution of the effects of adhesion to the bed among the interior particles of the fluid mass. The resistances may, therefore, be expressed by the product of the area of the surface which experiences resistance to motion, multiplied by a function of the velocities, the particular form of this function remaining to be determined by experiment. The mean velocity is to be deduced from this mean exterior velocity by applying the laws governing the action of cohesion.

"The investigations upon the Mississippi first revealed the laws governing the action of cohesion. * * *

"In any vertical plane parallel to the current there is a resistance to motion at the bottom and at the water surface. The latter is chiefly a transmitted resistance, probably arising from upward currents, occasioned by inequalities at the bottom, which retard the upper layer, not only by shocks and boils in breaking, but also by actually transferring water moving at a slow rate near the bottom to the surface. According to M. Bazin's views, the surface retardation is partly due to inequalities of movement occasioned by the relative absence of pressure, and it appears probable that this may be one cause of the phenomenon." (Jour. Fr. Inst., V. 65, p. 391.)

The "parabola" theory of vertical velocities, from surface to bottom, in a plane parallel with the current, is thus stated by him:

"The law of transmission in a vertical plane is represented by the arc of a parabola whose axis is parallel to the surface, and usually from one to three-tenths of the depth below it. The axis of this parabola moves up and down parallel to itself, as the relative resistances at the surface and bottom vary under the influence of winds or other extraneous forces. For the same depth and mean velocity the curve itself is unvarying. As the depth or mean velocity is changed the reciprocal of the parameter of the parabola varies in a manner expressed by $\sqrt{b\,v}$ in which $b = \dfrac{1.69}{\sqrt{Depth + 1.5}}$. The complete law of the change of velocity from surface to bottom, in any vertical plane parallel to the current is, therefore, given in feet, by the following equation in which $V d'$ denotes the maximum velocity, and d' the depth below the surface, at which it is located. V denotes velocity at any depth d, the total depth being D.

$$V = V d' - \sqrt{b\,v}\left(\frac{d - d'}{D}\right)^{2}"$$

(Gen. H. L. Abbot, Jour. Fr. Inst., V. 65, p. 392).

Taking Prony as an early authority, and Abbot as a final summary of the common theory of channel motion, we see no important distinction made from a supposed "stationary envelope" along the wet perimeter

which by adhesion and friction retards, in a certain order of diminution, the various layers gliding over each other, from the bottom to the surface, by regularly transmitted resistance.

In other words, the particles are assumed to move, normally, in parallel layers throughout the section, as other bodies move down inclined planes, and changes of velocity in these several layers result from resistances caused by a stationary envelope of the wet perimeter, and the resistances it transmits upward, and toward the thread of the stream.

TESTS OF THEORIES.

That waves of the second, third and fourth orders do not move in parallel layers down inclined planes, but in circles or curves, rolling as commingled wheels, or spheres down the slope of the channel, would naturally be inferred from the analogy of usual methods of motion, which may be briefly indicated as follows :

Gases : That gases and liquids obey common mechanical laws is well understood : under light or more powerful pressure the smoke from a chimney, or ten-inch gun, or locomotive, escapes into the air with its circles already formed, as does the exhaust steam. The well demonstrated law of diffusion of gases could not act as it does in a close vessel if motion occurred in parallel layers and not in curves : the strange tenacity of smoke and steam rings in the air illustrate the same law, as do the cirro cumuli clouds over our heads. The process of boiling where a gas is generated and escapes through water beautifully illustrates this motion : that the wind travels in whirls is plain, as are its eddies along the earth's surface and its more violent exhibitions of power, and the circular forms and motions of heat waves are well known.

Water Globules : From a rain drop to the great ocean itself, the tendency of water to form a sphere is universal, under the action of cohesion, motion and external friction. Rain drops passing through the resisting air retain their circular form by continuous revolutions, as well as by cohesion in their descent : the particles of a cascade illustrate the same law, while the sheet itself assumes, for a given time and a depth of fall only, a parabolic curve, under the combined forces which generate and then control its delivery and descent.

Surface resistance : Whether an object is forced through water, or water passes along resisting surfaces, its tendency to move in circles is obvious. One may lean over the taffrail of the "Bothnia," as she makes her fifteen knots through a smooth July sea, and study the endless succession of horizontal surface curves or eddies, generated along her midship section by "skin friction," quite uniform in diameter when not disturbed, and varied by her lazy roll, on the long sea swells ; leaning over her stern, the continuous roll of the return displacement waves, makes a long wake behind her. Froude's experiments on ship resistance show conclusively the action of hull displacement in eddy and wave making, where relative length and speed of hull are very important factors in the problem of reaction, resistance, wave length, and relative wave pressure against or behind the hull, as they rotate.

Horizontal Curves : In ordinary streams where there is bank velocity sufficient to show them numerous eddies are observed, which become horizontal friction rollers to the passing water, and protect the bank

from scour; and in floods, the surface exhibition of mid channel boils and swirls is common.

In discharging through submerged orifices, funnel shaped curves are generated, moving "with the sun," from the surface downward, the curve sections growing smaller and deeper, as the pressure and velocity increase.

In these and like cases, the tendency of water to move in circles along resisting surfaces, and under impulse, is evident on inspection. If this is true as to horizontal planes, it is equally so as to vertical planes of motion, and the particles and bodies of water do not slide over each other, like solids, but travel in circles, of varying velocities and dimensions, regulated by pressure resistance, and form of bed. If there is a "stationary envelope" to channel beds, it is an exceptional phenomenon in hydraulic motion.

The proof of this law, as a law, is convincing.

Motion of Bed Particles: Mr. Francis finds, in a canal of quite uniform motion and regular section, that coloring matter taken up at the bed is systematically carried to the surface down stream: its path has then been that of a cycloid, on a great wheel of motion.

Relative Temperature: The rapid depth reduction of temperature in still water is well known, the surface being so much exposed to solar action, and the coldier and heavier water tending to sink: Lake Cochituate, with 81 degrees at the surface had 51 degrees at 42 feet depth; with 68 degrees at the surface 48.5 degrees at 30 feet; Spot pond, with 78 degrees at the surface had 60 degrees at 28 feet depth; yet in a deep river like the Mississippi, Lt. Marr (Phys. and Hyd. Miss., p. 196) finds the surface and bottom temperatures equal, an impossibility for a "stationary envelope," or an imperfect interchange of particles from surface to bottom.

Bottom Scour: There is also a convincing proof of rolling motion along the bed and sides of a channel, in the negative results of the well-established law of scour due to adequate impinging velocity, shown by experiments of Blackwell and others, abundantly confirmed.

In a plank sluice, 4 feet wide by 3 feet deep, it took a velocity of 1.25 to 1.5 feet per second to start and move quarter-inch gravel and coal of 4.11 cubic inches; 2.5 to 2.7 square feet to start flints of 1.95 cubic inches; 2 to 2.25 feet to start brickbats of 4.76 cubic inches; and 3.5 to 3.75 to move the latter 1.2 feet per second (Beardmore, Man. Hyd., p. 7). Du Buat found the bottom velocity to move potter's clay 0.26 feet per second, fine sand 0.525, pea gravel 0.623, one-inch pebbles 2.132, egg flints 3.28 feet (D'Aubuisson, Hyd., p. 149). Generally the delta of rivers show their scouring action limited to clay, sand and gravel. His experiments also show a bottom deposit of sand in transverse furrows, with gentle up-stream slope and sharp down-stream face, the interspaces 0.394 foot and the rate of travel half an hour per furrow, under a stream flow of 0.984 foot per second, a striking example of slow circular action.

Yet, in such a powerful outlet as St. Clair River, at 47 feet depth, the velocity at 5 feet depth is 3.907 feet per second; at 42.4 feet, 2.388 feet; at 45.4 feet, 1.428 feet, the lowest sufficient to move not only clay and sand, but quarter-inch gravel.

In Bayou Plaquemine, delta bottom, 27 feet depth, at 20 feet, 6.02 feet per second. (Physics and Hydraulics Mississippi, p. 245). Mississippi, Vicksburg, about 75 feet depth ; at 70 feet, 6.82 feet per second ; Carrollton, 110 feet depth, at bottom, 3.87 feet per second (Id. p. 246) ; bottom formation sand, hard sand, clay, soft clay. Chesapeake & Ohio Canal feeder ; depth, 7.1 feet ; at 5 feet, 2.267 feet per second.

Here then are bottom velocities, in yielding strata, far in excess of severe scouring action, under a pressure, at 110 feet depth, of over 48 pounds per square inch, and no adequate scour is produced ; the bottom particles have this motion, and no stationary adhesion, and the result can only be explained by the action of a broad wheel tyre, and not that of a sliding stratum or plough.

River characteristics illustrate the same law. Shallow and narrow streams transport pebbles and bowlders, shallow and broad streams gravel and coarse sand, narrow and deep streams fine sand. Swifter and clear streams have more direct lines, less depth and greater inclination ; deep, muddy rivers winding lines, and broad channels, as the Nile and Mississippi.

Flood Waves : The line of swiftest descent in any channel tends to follow that of greatest depth, and forms a constant channel wedge, or convex projection, down stream, with side reactions. A flood wave in a channel, itself normally of the first order, combining with the stream wave of the second order, has a crest overlap and rotative motion, far superior in speed to that of the main body.

On the Ohio, as observed by an engineer like Charles Ellet, Jr., to whom hydraulic science is greatly indebted, with the Wheeling Bar showing an average annual depth, for six years, of 8.94 feet (Phys. Geog. Miss. Valley, Ellet, p. 43), with flood depths of 25 to 44.5 feet, it was found that the mean crest velocity, for a flood of 35 feet depth, was four miles per hour, with a central thread of five miles; while the total wave speed of a higher flood of 44.5 feet, from Pittsburgh to Louisville, 613 miles, was 2.28 miles per hour, about half the extreme crest speed of the 35-foot wave, that of the 44.5 being estimated at six miles per hour. In such a case the superior height and velocity of the front of the crest throws the drift toward the shore, while behind the wave crest a hollow wave draws the drift toward the centre, on the falling flood.

A flood in the Mississippi, July, 1858 (Phys. and Hyd. Miss., p. 268), is reported with a prism speed, for 304 miles, from Helena to Vicksburg, of 100 miles per day, or 4.16 per hour, or 6.11 feet per second. A calculation (p. 268), of the velocity of the volume added, above a given datum to flood level, between these points, gives 18.75 feet per second, or about three times the mean wave speed. The current velocities, July 17, 1858, at Vicksburg (App.), give a maximum of 8 feet, and a mean of 6.95 feet per second, 5 feet below the surface, velocities not being taken at lower depths, and assumed from parabolic formulæ. Maximum gauge depth, 48.1 feet ; discharge estimated, 1,229,100 cubic feet per second, as compared with minimum gauge depth, Oct. 25, 8.7 feet ; average velocity, 3.01 feet ; discharge, 233,320 cubic feet per second.

Such a channel, which within three months reduces its depth and dis-

charge, at one point, about five-fold, cannot very well demonstrate a rigid empirical formula.

B ach Formation: a peculiar instance of horizontal eddy action occurs in the extension of sand spits at the mouths of bays. In the Rockaway Beach case it was shown that such a spit projecting westerly, at the mouth of a bay, had gradually extended in a long and narrow line, for about 4½ miles, until it joined the main shore. Flood tide waves disturb and bring in sand; in its sweep around such a spit, inside eddies are formed which deposit this sand; the ebb tide eddies on the outside also deposit sand, and thus there is a constant elongation.

Ocean Waves: This argument of analogy might be enlarged with emphasis as to the various received definitions of waves of the third order, by profound students like Russell, Froude, Rankine and others; but the following quotation will suffice, in a paper limited as to its range:

"* * * It is quite sufficient to assume that the profile of a simple wave is trochoidal, and that the particles of water move in circles in a vertical plane at right angles to the ridges and valleys of the waves. * * * The diameter of the circle in which a surface particle moves is the height of the wave from hollow to crest. Particles, which in still water would be at a lower level, describe smaller circles in the same period. A horizontal plane (in the still water) is thus converted into a wave surface of the same period, but of reduced amplitude of oscillation. The velocity of the particles (and on this depends the *impact* of a wave) is simply the circumference of one of these circles divided by the periodic time." (Froude, Rankine, etc., Brit. Assoc. V. N., Mag., Vol 12, p. 290.)

CONCLUSION.

We have shown here, that water has common modes of motion, not usually examined in experiment, or defined in usual text book formulæ. It also appears that the Roman aqueduct section adopted by Major Douglass for the Croton has a large increase of flow, which shows that the ancient engineers were guided by principles prominent recent structures do not illustrate.

The analogies gathered from fluids, water spheres, ship eddies and circles, orifice discharge, stream motion, bank eddies, bottom temperature, and scour, flood waves, and ocean waves, and the analysis of the four orders of waves show, that the common theory of channel motion cannot be correct, and that the only progressive motion of parallel forms is in the primary wave, and is vertical and not horizontal in that case.

It becomes evident therefore, that formulæ must be modified by a system of experiments conformed to the true laws of motion and conditions of flow; and that the same co-efficients cannot be applied to different velocities in the same channel, or different waves, or to dissimilar sections; and that for waves of the second order each conduit or channel has a standard of maximum useful effect.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

OCTOBER 19, 1887 :—A regular meeting of the Boston Society of Civil Engineers was held in its rooms, Boston & Albany Railroad Station, Boston, at 7:40 P. M., President Rice in the chair. Forty-five Members and nine visitors were present.

The record of the last meeting was read and approved.

Mr. Phinehas Ball, of Worcester, and Mr. Lyman L. Gerry, of Stoneham, were elected Members of the Society.

The Government submitted a report in relation to the communication of the Board of Managers of the Association of Engineering Societies, and recommended the adoption of the articles proposed by the Board in the following amended form :

"ARTICLE I. The Boston Society of Civil Engineers authorizes the Board of Managers of the Association of Engineering Societies, on the favorable action of the American Society of Civil Engineers and two-thirds of the societies in the Association, to call a convention of delegates from the several societies of the Association, and such other societies as the Board may invite ; said convention to consider the question of an organization of the several societies of the country in a confederation, or such other union as may be found desirable. The Board is also empowered to lay before this convention such other matters as it may consider of general moment.

"ARTICLE II. The Board of Managers may determine the time and place for such a convention. The representation of each participating society shall be three votes, and one additional for each fifty or fraction thereof in excess of one hundred members.

"ARTICLE III. The conclusions of this convention shall not be binding upon any participating society until ratified by said society ; and when two-thirds of the participating societies have ratified the action of said convention, the proposed organization may go into effect."

On motion of Mr. Whitney, the report was accepted and the articles as amended were adopted.

The Secretary read a communication from the Committee on Metric System of the Western Association of Architects, asking the co-operation of the Society in petitioning Congress to pass a law making the use of the metric system compulsory in the various departments of the government. On motion of Mr. Tilden the communication was referred to the Committee on Weights and Measures.

Prof. L. M. Norton, of the Institute of Technology, read a paper prepared for the Society by the late William Ripley Nichols, entitled "The Action of Boston Water on Certain Sorts of Service-Pipe."

After reading the paper Professor Norton requested information in regard to the most satisfactory paint used for the preservation of bridges against the action of the atmosphere. Mr. Barlow, engineer of the new Tay Bridge, had asked him as to the American practice. Mr. Manley said that his experience led him to prefer red lead to any of the mineral paints he had tried. He believed that red lead would resist better than any other paint the action of salt water and the sulphurous gases from locomotives passing under bridges.

Mr. Parker thought that the secret of efficient painting lay in thoroughly cleaning the iron of scales before applying the paint.

Prof. G. F. Swain occupied the rest of the evening, speaking in an informal way on some matters regarding the dimensioning of bridge structures. Among others he gave the result of some investigations upon the distribution of wheel-loads over the floor system commonly found in railroad Howe truss bridges. He also gave a method for determining the proportion of load borne by the beam and the truss rod on the common form of king-post trussed beams, and discussed briefly the question of bending and compression combined. A formula for dimensioning was also suggested, based upon Wöhler's experiments, which was simpler in its application than any of the modifications of Launhardt's now in general use.

The various points raised by Prof. Swain's remarks were quite fully discussed by Messrs. Cheney, Davis, Keith, Rice, Shaw and Worcester.

[*Adjourned.*] S. E. TINKHAM, Secretary.

WESTERN SOCIETY OF ENGINEERS.

OCTOBER 4, 1887:—The 240th meeting was held at 8 P. M., President Artingstall in the chair.

The minutes of the preceding meeting were read and approved.

Mr. Moritz Lassig, Bridge Builder, 534 Garfield avenue, Chicago, and Mr. George H. Bremner, Assistant Engineer, West Iowa Division C., B. & Q. R. R., Red Oak, Iowa, were elected Members.

Mr. E. C. Shankland was transferred from the grade of Junior to that of Member.

Mr. John F. Barney, Contractor and Builder, 27½ Lakeside Building, Chicago, and Mr. Jacob Rodatz, Contractor and Builder, 27½ Lakeside Building, Chicago, were proposed as Members.

The Secretary presented a bill for $183 from the *Railroad Gazette*, for the August assessment for 183 copies of the *Journal*, which was ordered paid.

The Secretary read the following communication :

To the Western Society of Engineers:

I hereby resign the office of Secretary, and request to be relieved of its duties as soon as possible. L. P. MOREHOUSE, Secretary.

It was agreed that no action should be taken on the above until the next meeting.

Mr. Lundie presented a short paper containing a formula, and its mathematical demonstration, for determining the economical proportions of truss bridges. A discussion of this paper, when printed, is invited by the author.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

ENGINEERS' CLUB OF KANSAS CITY.

OCTOBER 3, 1887 :—A regular meeting was held at the Deardorff Building. There were present Messrs. J. A. L. Waddell, Clift Wise, G. W. Pearsons, R. C. Simons, Wm. Norris, C. G. Wade, T. F. Wynne, etc. J. A. L. Waddell, Vice-President, presiding. T. F. Wynne, Secretary pro tem.

Upon a canvas of the ballots, E. W. Sterns, Charles H. Talmage and Charles W. Hastings were elected Members.

The paper of the evening on "The construction and operation of the Ninth Street Cable Railway," prepared by Mr. M. K. Bowen, was read by Mr. C. G. Wade.

Mr. P. W. Kiersted was proposed for membership by Messrs. G. W. Pearsons and J. A. L. Waddell. Mr. Kiersted was invited and consented to read a paper at the next meeting, subject to be announced.

[*Adjourned.*] T. F. WYNNE, Secretary pro tem.

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. VI. December, 1887. No. 12.

CONCRETE.

BY JOHN LUNDIE, MEMBER OF THE WESTERN SOCIETY OF ENGINEERS.

[Read July 5, 1887.]

The subject of cements and concrete has been so well treated of in engineering literature, that to give an extended paper on the subject would be but the collection and reiteration of platitudes familiar to every engineer who has been engaged on foundation works of any magnitude. It shall therefore be the object of this communication to place before the Society several notes, stated briefly and to the point, rather as a basis for discussion than as an attempt at an exhaustive treatment of the subject.

Concrete is simply a low grade of masonry. It is a comparatively simple matter to trace the line of continuity from heavy squared ashlar blocks down through coursed and random rubble, to grouted, indiscriminate rubble, and finally to concrete. Improvements in the manufacture of hydraulic cements have given an impetus to the use of concrete, but its use is by no means of recent date. It is no uncommon thing in the taking down of heavy walls several centuries old, to find that the method of building was to carry up face and back with rubble in stiff mortar, and to fill the interior with boulders and gravel, the interstices of which where filled by grouting—the whole mass becoming virtually a monolith. Modern quick-setting cement accomplishes this object within a time consistent with the requirements of modern engineering works: the formation of a monolithic mass within a reasonable time and with materials requiring as little handling as possible being the desideratum.

The materials of concrete as used at present are cement, sand, gravel, broken stone, and, of course, water. It is, perhaps, unnecessary to say that one of the primary requirements in materials is that they should be clean. Stone should be angular, gravel well washed, sand coarse and sharp, cement fine and possessing a fair proportion of the requirements laid down in the orthodox specification. The addition of lime water, saccharated or otherwise, has been suggested as an improvement over water, pure and simple, but no satisfactory experiments are on record justifying the addition of lime water.

Regarding the mixing of cement and lime with saccharated water, the writer made some experiments several months ago by mixing neat cement and lime with pure water, and with saccharated water, with the

result that the sugar proved positively detrimental to the cement, while it increased the tenacity of briquettes of lime.

Stone which will pass a 2-inch is usually specified for ordinary concrete. It will be found that stone broken to this limit of size has 50 per cent. of its bulk voids. This space must be filled by mortar, or preferably by gravel and mortar. If the mixing of concrete is perfect the proportion of stone, by bulk, to other materials should be two to one. A percentage excess of other materials is, however, usually allowed to compensate for imperfection in mixing. While an excess of good mortar is not detrimental to concrete (as it will harden in course of time to equal the stone), still on the score of economy it is advisable to use gravel or a finer grade of stone in addition to the 2-inch ring stone to fill the interstices—gravel is cheaper than cement. The statement that excess of stone will give body to concrete is a fallacy hardly worth contradicting. In short, the proportion of material should be so graded that each particle of sand should have its jacket of cement, necessitating the cement being finer than the sand (this forms the mortar) : then each pebble and stone should have its jacket of mortar. The smaller the interstices between the gravel and stones, the better.

The quantity of water necessary to make good concrete is a sorely debated question. The quantity necessary depends on various considerations, and will probably be different for what appears to be the same proportion of materials. It is a well-known fact that brick mortar is made very soft, and bricks are often wet before being laid, while a very hard stone is usually set with very stiff mortar. So in concrete the amount of water necessarily depends, to a great extent, on the porosity or dryness of the stone and other material used. But as to using a larger or smaller quantity of water with given materials, as a matter of observation, it will be found that water should only be limited by its effect in washing away mortar from the stone. Where can better concrete be found than that which has set under water? A certain definite amount of water is necessary and sufficient to hydrate the cement ; less than that amount will be detrimental, while an excess can do no harm, provided, as before mentioned, that it does not wash the mortar from the stone. Again, dry concrete is apt to be very porous, which in certain positions is a very grave objection to it—this, not only from the fact of its porosity, but from the liability to disintegration from water freezing in the crevices.

Concrete, when ready to be placed in position, should be of the consistency of a pulpy mass which will settle into place by its own weight, every crevice being naturally filled. Pounding dry concrete is apt to break adjacent work, which will never again set properly. There should be no other object in pounding concrete than to assist it to settle into the place it is intended to fill. This is one of the evils concomitant with imperfection of mixing. The greater perfection of mixing attained the nearer we get to the ideal monolith. The less handling concrete has after being mixed, the better. Immediately after the mass is mixed setting commences ; therefore, the sooner it is in position the more perfect will be the hardened mass ; and, on the other hand, the more it is handled, the more is the process interrupted and in like degree is the finished mass deteriorated. A low drop will be found the best method of placing a

batch in position. Too much of a drop scatters the material and undoes the work of thorough mixing. Let the mass drop and then let it alone. If of proper temper, it will find its own place with very little trimming. Care should be taken to wet adjacent porous material, or the wooden form into which concrete is being placed ; otherwise the water may be extracted from the concrete, to its detriment.

It has been found on removing boxing that the portion adjacent to the wood was frequently friable and of poor quality, owing to the fact just stated. It is usual to face or plaster concrete work after removing the boxing. On breakwater work, where the writer was engaged, the wall was faced with cement and flint grit, and this was found to form a particularly hard and lasting protection to the face of the work.

Batches of concrete should be placed in position as if they were stones in block masonry, as the union of one day's work with a previous is not by any means so perfect as where one batch is placed in contact with another which has not yet set. A slope cannot be added to with the same degree of perfection that one horizontal layer can be placed on another ; consequently, where work must necessarily be interrupted, it should be stepped, and not sloped off.

Experience in concrete work has shown that its true place is in heavy foundations, retaining walls and such like, and then perfectly independent of other material. Arches, thin walls, and such like, are very questionable structures in continuous concrete, and are on record rather as failures than otherwise. This may to a certain degree be due to the high co-efficient of expansion Portland cement concrete has by heat. This was found by Cunningham to be 0.000005 of its bulk for one degree Fahrenheit. It is a matter which any intelligent observer may remark, the invariable breakage of continuous concrete sidewalks, while those made in small sections remain good. This may be traced to expansion and contraction by heat, together with friction on the lower side.

In foundations, according to the same authority above quoted, properly made Portland cement concrete may be trusted with a safe load of 25 tons per square foot.

In large masses, concrete should be worked continuously, while in small masses it should be molded in small sections, which should be independent of each other and simply form artificial stones.

The facility with which concrete can be used in founding under water, renders it particularly suitable for sub-aqueous structures. The method of dropping it from hopper barges in masses of 100 tons at a time, inclosed in a bag of coarse stuff, has been successfully employed by Dyce Cay and others. This can be carried on till the concrete appears above water, when the ordinary method of boxing can be employed to complete the work. This method was employed in the North Pier breakwater at Aberdeen, the breakwater being founded on the sand, with a very broad base. The advantage of bags is apparent in the leveling off of an uneven foundation. In breakwater works on the Tay, in Scotland, where the writer was engaged, large blocks perforated vertically were employed. These were constructed below high water mark, and an air-tight cover placed over them. They were lifted by pontoons as the tide rose, and conveyed to and deposited in place, the hollows being filled with air, serving to give buoyancy to the mass. After placing in position the ver

tical hollows were filled with concrete, so binding the whole together — they being placed vertically over each other.

As mentioned before, continuous stretches of concrete in small sections should be guarded against, owing to expansion by heat; but the fact of a few cracks appearing in heavy masses of concrete should not cause apprehension. These occur from unequal settlement and other causes. They should continue to be carefully grouted and faced until settlement is complete.

The use of concrete is becoming more and more general for foundation works. The desideratum hitherto has been a perfect and at the same time an economical mixer. Concrete can be mixed by hand and the materials well incorporated, but this is an expensive and man-killing method, as the handling of the wet mass by the shovel is extremely hard work, besides which the slowness of the method allows part of a large batch to set before the other is mixed, so that small batches, with attendant extra handling, are necessary to make a good job. Mixers with a multiplicity of knives to toss the material have been used, but with little economical success. Of simple conveyers, such as a worm-screw, little need be said; they are not mixers, and it seems a positive waste of time to pass material through a machine when it comes out in little better shape than it is put in. A box of the shape of a barrel has been used, it being trunnioned at the sides. The objection to this is that the material is thrown from side to side as a mass, there being a waste of energy in throwing about the material in mass without accomplishing an equivalent amount of mixing. Then a rectangular box has been used, trunnioned at opposite corners; but here the grave objection is, that the concrete collects in the corners, and after a few turns it requires cleaning out, the material so sticking in the corners that it gets clogged up and ceases to mix.

The writer has just protected by letters patent a machine, in devising which the following objects were borne in mind:

1st. That every motion of the machine should do some useful work. Hitherto box or barrel mixers have gone on the principle of throwing the material about indiscriminately, expecting that somehow or other it would get mixed.

2d. That the sticking of the material anywhere within the mixer should be obviated.

3d. That an easy discharge should be obtained.

4th. That the water should be introduced while the mixer revolves.

With these desiderata in view, a box was designed which in half a turn gathers the material, then spreads it, and throws it from one side to the other at the same time that water is being introduced through a hollow trunnion.

It is also so constructed that all the sides slope steeply toward the discharge, and there is not a rectangular or acute angle within the box. A machine has now been worked steadily for several weeks, putting in the concrete in the foundations of the new Jackson street bridge in this city, by General Fitz-Simons. The result exceeds expectations. The concrete is perfectly mixed, the discharge is simple, complete and effective, and at the same time the cost of labor in mixing and placing in position is lessened by 50 per cent. as compared with any known to have been put in under similar circumstances.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

NOVEMBER 16, 1887:—A regular meeting was held at the Society's rooms, Boston & Albany Railroad Station, Boston, at 7:30 P. M., President Rice in the chair, 59 Members and 25 visitors present. The record of the last meeting was read and approved. Mr. Charles E. C. Breck was proposed for membership by Messrs. J. H. Curtis and F. W. Hodgdon.

The Committee on Weights and Measures submitted a report on the communication from the Western Association of Architects asking the co-operation of the Society in an effort to secure the introduction of the metric system, and suggesting a "concert of action in bringing the matter to the attention of Congress at its next session, and that the effort for the present be limited to securing the adoption of the metric system by all the departments of the government for all government business."

The Committee recommended that a canvas of the Society be made to ascertain the opinions of the members on the proposition submitted by the Association of Architects. On motion of Mr. Brackett the report was accepted and the recommendation adopted.

On motion of Mr. Woods the usual appropriations were made for renewing subscriptions to the Society's periodicals and for binding.

Mr. Arthur V. Abbott, chief engineer of the National Super-Heated Water Company, of New York, gave a very full description of the plant now being built by the Boston Heating Company. A full size section of the street mains with the expansion joint, house-connection, and other parts of the system were exhibited and explained in detail.

[*Adjourned.*] S. E. TINKHAM, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

NOVEMBER 2, 1887:—The Club met at 8:10 P. M. at Washington University, President Potter in the chair, nineteen Members and one visitor present. The minutes of the meetings of May 4 and 18 were read and approved. The Executive Committee reported the doings of its meetings of October 26 and November 2. It also submitted the following report on programme, which was adopted:

ST. LOUIS, Nov. 2, 1887.

GENTLEMEN: Your Executive Committee beg leave to submit the following programme of the Club's work for the coming year. Meetings have been arranged for the first and third Wednesdays of each month up to June next. It is not expected that this plan can be rigidly adhered to, but it will serve as a basis to work upon and will be followed as closely as circumstances permit.

November 2.—Chas. E. Jones, "Steam Heating at Washington University."

November 16.—Prof. J. B. Johnson, "Testing the Strength of Engineering Materials."

December 7—Annual Meeting.—P. M. Bruner, "The Action of Frost on Concrete Work."

December 21.—Isaac A. Smith, "Rapid Railway Embankment Construction."

January 4.—Chas. H. Ledlie, "Construction of Dam and Reservoir at Athens, Ga.;" Chas. W. Bryan, "Railway Bridge Designing."

January 18.—Carl Gayler, "Floors of Street Bridges;" N. W. Eayrs, "The Improvement of Nantucket Harbor, Mass."

February 1.—Prof. F. E. Nipher, "Graphical Solution of the Action of the Series Dynamo;" B. F. Crow, "Constructive Accounts."

February 15.—Robert Moore, "Sizes of Railroad Culverts;" O. L. Petitdidier, "Practical Notes on Masonry and Stone Laying."

March 7.—Prof. H. B. Gale. "The Transmission of Power by Belting;" Samuel F. Burnet, "Cement and Mortar."

March 21.—Prof. W. B. Potter, "St. Louis Water Supply."

April 4—S. Bent Russell. "Thickness of Water Pipes;" H. A. Wheeler [subject not yet announced].

April 18.—Prof. C. M. Woodward, "Gas Producers;" Lewis Stockett. "A Well Ventilated Mine."

May 2.—Col. E. D. Meier, "Standards of Boiler Efficiency;" Charles F. White. "The Failure of a Firmenich Boiler."

May 16.—R. E. McMath. "The Waterway between the Lakes and the Mississippi River."

June 6.—M. L. Holman, "The Temporary Low Service Pumping Plant a St. Louis."

Partial promises have been made of other papers on topics of interest. These will be presented as opportunity occurs and due notice given.

EXECUTIVE COMMITTEE. W. H. BRYAN, Sec'y.

The following applications for Membership were announced and referred to the Executive Committee: Allan C. Glasgow, indorsed by M. L. Holman and S. B. Russell; Robert F. Grady, indorsed by J. A. Seddon and J. B. Johnson; John A. Laird, indorsed by W. W. Penney and S. B. Russell: Frank Nicholson, indorsed by W. B. Potter and E. A. Engler: Peter W. Schaumleffel, indorsed by W. H. Bryan and Chas. W. Melcher; John P. Thul, indorsed by C. M. Woodward and J. B. Johnson.

Professor Johnson read a communication from the Board of Managers of the Association of Engineering Societies, on the subject of a closer union between the societies now in the association and others. On motion the consideration of this paper was made a special order for the next meeting, November 16.

Mr. Chas. E. Jones then read a paper on "Steam Heating at Washington University, and Experience with Underground Pipes." The history of the system in use was given, with details of its construction and the work done. It was shown that the boilers were regularly doing double the duty which was originally expected of them. The evaporative efficiency did not seem to be reduced when the boilers were forced in this manner. Great efforts had been made to reduce the smoke and many devices had been tested. All had failed on account of the excessive duty required of the boilers. The underground pipes had failed after years of service from external corrosion due to the accidental admission of moisture to the conduits. New pipes had been laid recently and the construction of the new conduit was shown.

Professors Woodward, Potter, Gale and Messrs. Bryan and Sharman took part in the discussion. Mr. Jones added that a new stack had just been erected, which had increased the draft sufficiently to permit the introduction of a small amount of air above the grates. This had resulted in an appreciable reduction of the smoke.

[*Adjourned.*] WM. H. BRYAN, Secretary.

NOVEMBER 16, 1887:—The Club met at Washington University at 8:05 P. M., President Potter in the chair, thirty Members and four visitors present. The minutes of the last meeting were read and approved. The doings of the Executive Committee meetings of October 21st and November 16th were reported. The Committee recommended the following persons for election to membership: A. C. Glasgow, R. F. Grady, J. A. Laird, Frank Nicholson, P. W. Schaumleffel, and J. P. Thul. On balloting all were elected. The following applications for membership were announced and referred to the Executive Committee: Reno DeO. Johnson, indorsed by Wm. B. Potter and Wm. H. Bryan: Oscar W. Raeder, indorsed by C. E. Jones and C. F. White; James C. Simpson, indorsed by Louis Stockett and Wm. B. Potter: Albert H. Zeller, indorsed by J. B. Johnson and C. M. Woodward.

The regular order of the day was then taken up, being a communication from the Board of Managers of the Association of Engineering Societies. The discussion was participated in by Col. H. C. Moore, Profs. Johnson and Nipher, Messrs. Robt. Moore, Russell, Seddon, Ockerson, Bryan and R. E. McMath; also, on invitation, by Mr. A. W. Wright, of Chicago. On motion, the following was adopted:

Resolved, That in the opinion of the Engineers' Club of St. Louis, an attempt at an organic union is not desirable. We therefore decline to favor the recommendation of the Board of Managers.

The following committee on nominations of officers for the coming year was then elected: J. A. Seddon, chairman: R. E. McMath, S. B. Russell, E. A. Engler, J. A. Ockerson. Prof. Johnson then read a paper on "Testing the Strength of Engineering Materials." His remarks were illustrated by sketches on the board; he also showed numerous test pieces of iron, steel, brick, stone and wood; also a small testing machine as used. The professor called attention to the action of members of engineering structures, first, when the stresses was applied and removed repeatedly: and, second, when in addition they were reversed. The professor applied the terms "repetition limit" and "reversal limit" to the maximum loads that could be applied under such conditions, and gave simplified formulæ for expressing same. The experimental research necessary for determining results under these conditions required great time, but he was confident that eventually data of great value would be secured. It was shown that to load a member slightly beyond its elastic limit did not necessarily injure it; in fact, to thus "take the stretch out of it" might even benefit it for some purposes. The paper was discussed by Messrs. Russell, Moore, Engler, Seddon, Potter and Nipher, the latter exhibiting a cast-iron cap which had been attached to the bottom of a piece of wrought-iron pipe filled with water, and broken by firing a rifle ball from above into the water.

[*Adjourned.*] W. H. BRYAN, Secretary.

WESTERN SOCIETY OF ENGINEERS.

NOVEMBER 1, 1887:—The 241st meeting was held at 8 P. M., President Artingstall in the chair.

The minutes of the preceding meeting were read and approved.

Mr. John F. Barney, contractor and builder, No. 27½ Lakeside Building, Chicago, and Mr. Jacob Rodatz, contractor and builder, No. 27½ Lakeside Building, Chicago, were elected Members of the Society.

The resignation of Mr. Morehouse as Secretary, tendered at the preceding meeting, was discussed.

Mr. C. L. Strobel offered a resolution authorizing the President to appoint a committee of three to take steps toward due recognition of the services of Mr.

Morehouse to the Society, and to nominate a successor. This being carried, the President nominated as a committee Messrs. Fitzsimons, Bates and Strobel, the committee to report at next meeting.

A communication was read from Mr. H. L. Gay, calling the attention of Members present to a display of work by the students in the engineering department of the Ann Arbor College, Michigan.

Mr. Scherzer presented a discussion of the paper read by Mr. Lundie at the preceding meeting, on "The Economical Height of Bridge Trusses." The paper was discussed, also, by Messrs. Artingstall and Strobel.

It was intimated by the President that at the next meeting a paper would be read by Mr. Fiend on "Field Work." with special reference to contouring.

[*Adjourned.*] JOHN LUNDIE, Secretary pro tem.

ENGINEERS' CLUB OF KANSAS CITY.

NOVEMBER 7, 1887:—A regular meeting of the Engineers' Club of Kansas City was held at the Club Room, 19 Deardorff Building, at 7:45 P. M. There were present Messrs. W. B. Knight, A. J. Mason, E. B. Kay, A. E. Swain, C. E. Taylor, S. A. Mitchell, T. F. Wynne, E. W. Stern. Clift Wise, Kenneth Allen and five visitors.

On a canvass of ballots by the Executive Committee, Mr. Wynkoop Kiersted was elected a Member.

The minutes of the last meeting of the Club and of the Executive Committee were read and approved.

The Secretary read a letter from the Executive Board of the Council of Engineering Societies inviting co-operation.

On motion of Mr. Kay it was voted that the President appoint a committee of three to act in conjunction with the other committees of the Council.

The President appointed Messrs. Wise, Breithaupt and Chanute.

Victor M. Witmer was proposed as Associate Member by E. B. Kay.

Mr. Wynkoop Kiersted read a paper on "Water Supply and its Development for Small Cities in the West," which was then discussed.

[*Adjourned.*] KENNETH ALLEN, Secretary.

INDEX DEPARTMENT.

ANNUAL SUMMARY.

It is proposed to furnish, in this department, as complete an Index as may be of current engineering literature of a fragmentary character. A short note will be appended to each title, intended to give sufficient information to enable the reader to decide whether or not it is worth his while to obtain or consult the paper itself. The Index will be mostly limited to society and magazine articles, and special engineering reports of general interest and value. It is printed in the monthly issues of the JOURNAL, *on but one side of the paper, so that the titles may be cut out and pasted on cards or in a book, and is here collected with additional titles and many cross-references.*

All readers of the JOURNAL *are requested to aid in making the Index as complete as possible. All notices for this department, and all matter to be here indexed, should be sent to* J. B. JOHNSON, *Manager Index Department, Washington University, St. Louis, Mo.*

Abutments. By Wm. Cain. An investigation of their proper proportions and sizes, deduced from Rankin's general formula of earth pressure. *Van Nos. Eng. Mag.*, Vol. VII., p. 453.

Accidents in 1886. Tabulated statement of train accidents for 1886 classified; also the accidents for 14 years tabulated according to nature and cause. *R. R. Gaz.*, Jan. 28, 1887.

Accumulator, *The Montaud.* Full account of the construction and power of the above battery. *Sci. Am. Supple.*, June 18. 1887.

Adjustment of a traverse by the method of least squares. *Zeitch. f. Vermessungswesen*, 1887, pp. 249–271, 287–297.

Adjutages, *Submerged, Experiments with.* By C. W. Clark. Gives details and results of experiments made at the University of Illinois. *Jour. Assoc. Engr. Soc.* Vol. VI., p. 398.

Alloys, *Tests of.* *See* Tests and also Bronzes.

Aluminium. Process of Dr. Kleiner, of Zurich, for the production of the metal direct from cryolite. *Engineering*, March 25, 1887.

——, *Production of, with Special Reference to the Electrical Method.* By Dr. Vander Weyde, before the Am. Inst. *Elect. World*, Jan. 15, 1887.

——. Notes by Messrs. Cowles, with tables of physical properties. *Railroad Gazette*, Oct. 21, 1887.

——. Abstracts from a report of Prof. Unwin on the results of the tests of a bar of aluminium bronze produced by the Cowles process. Gives breaking weight, 37 tons per square inch; elongation. 30 per cent.; elastic limit, 18 tons per square inch. *Engineer*, Jan. 7, 1887; also see *Engineer*, Jan. 21, 1887.

—— *for Ordnance and Armor Plate.* Defects in present steel guns and probable advantages to be gained by substituting aluminium bronze. By R. C. Cole, in *Engineering and Mining Journal* for Jan. 22, 1887.

——. Its production by means of the Cowles Electric Furnace. Thomas D. West, *American Machinist*, Oct. 16, 1886.

Ammoniacal Gas *as a Motive Power.* By Emile Lamm. Gives short history of ammonia and the method employed to convert it into a liquid Also gives details of experiments made with a motor using ammonia gas instead of steam. *Van Nos. Eng. Mag.*, Vol. V., p. 290.

Anchor Ice, *Stoppage of Flow in a Water Main by.* By James B. Francis. Gives detail of the stoppage of flow at the Carleton, N. B., water-works by anchor ice. With discussion in *Trans. Am. Soc. of C. E.* Vol. XVI., p. 171; *Am Eng.*, July 13, 1887; also editorial *Am. Eng.*, July 20, 1887.

Angle Bars. *Why Do They Break?* By J. A. Weiss, before the Club of Engrs. of Maint. of Way, South-Western System, Pennsylvania. *R. R. Gaz.*, Jan 14, 1886.

Annual Address. A review of the great projects of the year. By Washington Jones, the retiring President of the Philadelphia Engineers' Club. *Proc Eng. Club, Phila.*, Vol. VI., p. 81.

—— *Before Am. Soc. of C. E.* By William E. Worthen. Gives résumé of the work of engineers during the past year. *Eng. News*, July 9, 1887; *San. Eng.*, July 16, 1877.

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